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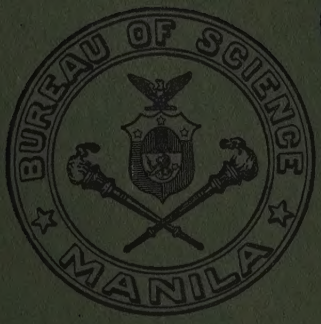

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THE FERMENTATION OF CASSAVA AND MOLASSES FOR THE PRODUCTION OF ACETONE AND NORMAL BUTYL ALCOHOL

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Of the various fermentation processes the production of acetone and normal butanol probably ranks second only to the yeast-alcohol industry in commercial importance, due to the fact that these two chemicals or their derivatives are used extensively as solvents, especially for the manufacture of lacquers, paints, varnishes, dopes, and explosives; as raw materials for the preparation of esters, perfumes, and pharmaceuticals; and as blending agents or stabilizers for composite motor fuels.

In the United States corn has generally been employed for the production of acetone and normal butanol. Lately, due to a tendency for the price of this cereal to go up as a result of crop reduction programs, investigators have been occupied in the search for cheaper raw materials. Recently Underkofler, Fulmer, and Rayman(8) indicated the possibility of employing xylose as a source of solvents.

In the Philippines there are a number of minor agricultural crops, such as the different kinds of tubers, which are rich in starch. If it can be shown that some of these can be used profitably as raw materials for the manufacture of industrial chemicals and other useful products, some of the farmers may be encouraged to grow them on a large scale, thus providing one of the possible inducements for the raising of diversified crops.

It appears from available literature that cassava (*Manihot utilissima* Pohl) is one of the few amylaceous materials that have not been employed for the production of acetone and normal butanol. At least cassava is not mentioned specifically as a source of solvents by Smyth and Obold.(6) In the case of molasses, a number of procedures have been described regarding its utilization in the butyl-acetonic fermentation process; but, according to Owen,(4) many of these procedures have not been successful from a commercial standpoint.

MATERIALS AND METHODS

Bacterial culture.—The original organism was isolated from rice field soil in October, 1937, according to the method of Weyer and Rettger.(10) It agrees in its cultural and morphological characteristics with two strains of *Clostridium acetobutylicum* (Weizmann) which were kindly furnished by Prof. E. B. Fred, of the University of Wisconsin, whose courtesy we wish gratefully to acknowledge. It was kept as a spore culture in soil and handled in the usual manner, 6.3 per cent sterile corn mash [1] being used as stock medium for the cultures and control fermentation tests.

It was observed in the beginning that, although the organism fermented corn mash vigorously with good yields of solvents, it was unable to utilize completely either the cassava or molasses, in spite of the presence of what were later found to be adequate nutrients. This difficulty was overcome by gradually acclimatizing it to grow in the presence of these materials through repeated subculturing, sporulation, and "heat-shocking," as practiced by Underkofler, Christensen, and Fulmer.(7) By this method we were able to develop two substrains, one of which was especially adopted for cassava and the other for molasses.

Preparation of mashes.—The cassava material used is known as "gaplex," and consists of dried sliced tubers of the plant. It was ground into a powder, and its starch content and the sugar content of the molasses determined according to the methods of the Association of Official Agricultural Chemists (1935). Unless otherwise stated, the mashes were prepared in such concentrations that their total carbohydrate contents were equivalent to 4 per cent starch. These mashes were sterilized in an autoclave for 2 hours at 15 pounds pressure. After sterilization they were cooled in running water and inoculated at once, 5 cc

[1] At this concentration the corn mash contained 4 per cent starch. Expressed in terms of dextrose, the carbohydrate content was $(4 \div 0.9 =)$ 4.44 per cent.

of an active bacterial culture being used per 100 cc of mash. The fermentations were carried out aërobically at 37° C. In order to minimize any loss of solvents through evaporation, the mouths of the flasks or bottles used in the fermentation experiments were covered with cellophane tied with rubber bands.

Analytical methods.—The total acidity is expressed in terms of the number of cc of 0.1 normal sodium hydroxide solution required to neutralize 10 cc of the medium, with phenolphthalein as indicator. The acetone was determined according to Goodwin's(3) modification of Messinger's method, and the normal butyl and ethyl alcohols according to the oxidation methods of Christensen and Fulmer.(1)

The solvent yields are given either in grams per 100 cc of culture or in terms of the dextrose equivalent of the total carbohydrate in the medium. In the latter case the following calculation will serve as an example: When 5 grams of solvents were obtained from a medium with a total carbohydrate content equivalent to 20 grams of dextrose, the yield was 25 per cent.

EXPERIMENTAL

Fermentation of mashes supplemented with corn meal.—Our early experiments demonstrated that mashes prepared from either cassava or molasses alone cannot support healthy bacterial growth, due to lack of adequate nutrients. For this reason it was necessary to supplement them with materials that are known to be rich in nutrients. In one series of tests patterned after those of Underkofler, Christensen, and Fulmer,(7) the mashes were mixed with varying amounts of corn mash, the object being to determine the maximum quantity of cassava or molasses that can be utilized to substitute the corn meal without lowering the yield of solvents. The results are presented in Table 1.

The data show that cassava can be employed to replace as much as 90 per cent, and molasses only 60 per cent, of the corn meal without diminishing the production of solvents. In other words, the addition of about 0.6 gram of corn meal per 100 cc of cassava mash containing 4 per cent starch will supply sufficient nutrients to support the healthy growth of the acetone butyl alcohol organism. In the case of molasses, about four times as much more corn meal had to be added, but even then the fermentation has not always been satisfactory.

TABLE 1.—*Fermentation of mashes mixed with corn meal.*

Corn meal replaced.	Total solvent yield, per cent of dextrose equivalent.	
	Cassava (gaplex).	Molasses.
Per cent.		
0	35.7	35.4
10	35.1	34.9
20	35.8	35.3
30	36.0	34.8
40	36.0	34.7
50	35.8	35.0
60	36.3	35.3
70	35.9	33.3
80	36.0	28.0
90	35.6	13.3
100	23.8	5.3

Fermentation of mashes supplemented with soybean.—The use of soybean as a source of nutrients was suggested by its high protein content and by the recent work of Weizmann and Rosenfeld,[2](9) who reported that legumes in general are good sources of asparagine and a substance known as "activator," these two compounds, according to the authors, being required for a normal butanol-acetone fermentation. The beans were powdered and mixed with the mashes in varying amounts. The results are given in Table 2.

TABLE 2.—*Fermentation of mashes mixed with soybean.*

Soybean added.	Total solvent yield, per cent of dextrose equivalent.	
	Cassava (gaplex).	Molasses.
g.		
0	18.8	2.9
0.2	33.1	19.4
0.3	34.7	22.3
0.4	36.1	35.3
0.5	36.0	35.2
0.7	36.4	35.6
0.9	36.1	34.9
1.0	36.3	35.5
1.2	35.4	33.4

[2] Later our attention was called to the work of Corbett(2) who utilized mixtures of tungseed meal, soybean and (or) peanut meal for the production of solvents. In some of our experiments we employed powdered mongo seeds in place of the soybean with satisfactory results.

According to the data, at least 0.4 gram of soybean powder is required to furnish the necessary nutrients for the fermentation of both cassava and molasses mashes, the carbohydrate contents of which are equivalent to 4 per cent starch. If more concentrated mashes are to be fermented, the quantity of soybean should be increased in direct proportion to the amount of carbohydrate present to obtain good solvent yields.

Soybean has been found to be a better source of nutrients than corn. It is more economical to use and in our hands it has given more uniformly satisfactory results than corn. The procedure is very simple, and for fermenting molasses it is believed to be less costly than the Arroyo process, even as modified by Owen.(4)

Chemical changes during fermentation.—In this experiment 2,000 cc each of soybean-cassava and soybean-molasses mixtures were placed in a separate flask and sterilized. Immediately after inoculation and at certain intervals thereafter, aliquot portions were removed, with aseptic precautions, for chemical analyses. The object was to determine the duration of the fermentation period and the nature of the chemical changes which take place during the process.

The data presented in Table 3 show that, insofar as the maximum production of solvents is concerned, the fermentation is complete after 69 hours in the case of cassava and after 93 hours in the case of molasses. These figures represent the maximum periods required for the fermentation of these two materials, for in other sets of experiments the fermentations were carried through in much less time. The chemical changes were quite similar to those observed by Peterson and Fred(5) and other investigators during the fermentation of corn; namely, much gas formation, the rapid rise and sudden fall in the acidity of the medium, formation of a "head" due to the buoying up of insoluble particles in the medium by the escaping gas bubbles, the subsequent falling of the "head" to the bottom of the container towards the end of the fermentation and its partial disintegration, the production of solvents, and the secondary rise in the acidity of the medium. The yield of total solvents from either cassava or molasses ranged from 34 to 38 per cent of the dextrose equivalent of the carbohydrate content of the mash and had an average composition of approximately 31 per cent of acetone, 58 per cent of normal butanol, and 11 per cent of ethyl alcohol.

TABLE 3.—*Chemical changes during fermentation.*

Hours after inoculation.	Yield of solvents per 100 cc of medium.									
	Cassava (gaplex).					Molasses.				
	Total acidity.	Acetone.	N-butyl alcohol.	Ethyl alcohol.	Total solvents.	Total acidity.	Acetone.	N-butyl alcohol.	Ethyl alcohol.	Total solvents.
	cc.	*g.*	*g.*	*g.*	*g.*	*cc.*	*g.*	*g.*	*g.*	*g.*
0	0.5					1.6				
4	0.7					1.8				
21	4.2	0.015				6.8	0.108	0.220	0.030	0.358
28	5.6	0.017				7.0	0.124	0.192	0.055	0.371
44	3.3	0.375	0.733	0.150	1.258	6.4	0.178	0.325	0.089	0.592
50	4.5	0.462	0.843	0.174	1.479	3.7	0.391	0.800	0.126	1.317
69	4.6	0.485	0.952	0.146	1.583	3.2	0.470	0.943	0.148	1.561
93	4.7	0.470	0.904	0.180	1.554	3.5	0.493	0.997	0.179	1.669
117	4.7	0.426	0.912	0.150	1.488	4.5	0.468	0.982	0.147	1.597
140	4.6	0.392	0.887	0.148	1.427	4.4	0.414	0.947	0.133	1.494

Yield of solvents from mashes of different concentrations.—In this experiment mashes of different concentrations were fermented under conditions as uniform as possible for the entire lot. The object was to determine the optimum carbohydrate concentration of the mashes which will give maximum yields of solvents.

The data given in Table 4 show that the highest yields of solvents per sugar unit were obtained from mashes with carbohydrate contents equivalent to between 4.06 and 5.56 grams of dextrose per 100 cc of medium. Of these, mashes 3 to 7, which contained from 4.06 to 5.27 per cent dextrose, gave slightly higher yields per sugar unit than mash 8. The concentration of the solvents in the beers, however, was lower, so that the amount of solvents per 100 cc of medium was actually smaller than that in mash 8. Dilute beers are disadvantageous to handle in the commercial production of solvents, because they necessitate larger distillation space. For this reason it is more economical to work with a more concentrated mash, as represented by mash 8. The latter can be easily prepared from molasses, but unfortunately not from cassava. The most concentrated cassava mash that we have used had a starch content equivalent to 5.23 per cent dextrose. If prepared in more concentrated form, the resulting mash would be too thick in consistency and difficult to handle.

The maximum amount of total solvents obtained from mash 8 was 2.040 grams per 100 cc of medium. Mashes 9 to 13, which

TABLE 4.—*Yields of total solvents from mashes of different concentrations (soybean, being used as the source of nutrients).*

Mash.		Carbohydrate content as dextrose per 100 cc of medium.	Total solvent yield.	
Number.	Constituent.		Grams per 100 cc of medium.	Dextrose equivalent.
		g.		*Per cent.*
1	molasses	3.50	1.240	35.4
2	do	3.72	1.351	36.3
3	do	4.06	1.508	37.1
4	do	4.36	1.614	37.0
5	do	4.65	1.723	37.0
6	do	5.02	1.849	36.8
7	do	5.27	1.969	37.4
8	do	5.56	2.040	36.7
9	do	5.87	1.984	33.8
10	do	6.16	2.032	33.0
11	do	6.61	1.900	28.7
12	do	7.27	1.899	26.1
13	do	7.93	2.035	25.6
14	gaplex	3.38	1.267	37.5
15	do	3.80	1.429	37.6
16	do	4.36	1.650	37.8
17	do	4.79	1.817	38.0
18	do	5.28	1.966	37.6

had sugar contents higher than 5.56 per cent, did not yield larger amounts of solvents, probably due to the inability of the vegetative phase of the butyl organism to withstand the presence of solvents in quantities much greater than 2 grams per 100 cc of medium. In other words, the fermentation process stops when the concentration of the fermentation products in the mash has reached a certain limit.

SUMMARY AND CONCLUSIONS

1. A strain of *Clostridium acetobutylicum* (Weizmann), which was isolated from rice field soil, was used as the fermenting agent.

2. Mashes prepared from either cassava or molasses alone cannot maintain the normal growth of the acetone-butyl alcohol organism, due to lack of adequate nutrients. For this reason it is necessary to supplement them with materials, such as corn meal or soybean powder, which are rich in nutrients.

3. Soy bean is better than corn as a source of nutrients. The addition of at least 0.4 gram of soybean powder to every 100 cc of mash with a carbohydrate content equivalent to 4 per cent starch will furnish the necessary nutrients for the fermentation of either cassava or molasses. The procedure is simple

and is believed to possess a slight advantage over the Arroyo process for the production of solvents from molasses.

4. The ability of *Clostridium acetobutylicum* to utilize cassava and molasses can be increased by gradually acclimatizing it to grow in the presence of these substances through repeated subculturing, sporulation, and heat-shocking.

5. With the use of derived cultures, the fermentations are complete after a period not exceeding 69 hours in the case of cassava-soybean mixtures and 93 hours in the case of molasses-soybean mixtures.

6. The yield of total solvents is from 34 to 38 per cent of the dextrose equivalent of the carbohydrate content of the mash and has an average composition of approximately 31 per cent acetone, 58 per cent normal butanol, and 11 per cent ethyl alcohol. The average yield from 1 kilo of cassava (gaplex) is 0.8 lb. and from 1 gallon of molasses 2.5 lbs. of total solvents.

7. Mashes with carbohydrate contents equivalent to between 4.06 to 5.56 grams of dextrose per 100 cc of mash give the highest yields of solvents per sugar unit. At the optimum sugar concentration of 5.56 per cent, the maximum yield is 2.040 grams of total solvents per 100 cc of mash. Mashes with higher carbohydrate contents do not yield larger amounts of solvents, due probably to the inability of the vegetative phase of the butyl organism to withstand the presence of solvents at higher concentrations.

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PHOSPHORUS STUDIES ON PHILIPPINE SOILS, I

THE READILY AVAILABLE PHOSPHORUS OF SOILS AS DETERMINED BY THE TRUOG METHOD [1]

By RICARDO T. MARFORI [2]

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Various rapid chemical tests that are a distinct aid in ascertaining the state of fertility of soils have been developed in different parts of the world. But the wide variation in soils, climate, and other crop requirements limits the application of such rapid tests to regions or localities where these tests have been well standardized against field results. No single test that has proven useful in estimating the fertilizer requirements of certain crops in a certain region can claim reliability for all crops in all kinds of soils.(13)

Harper(6) reported that the Truog method(15) for determining the easily soluble phosphorus content of soils gave a fairly good correlation with the response of eight farm crops to phosphorus fertilization on eighty-three soils from different parts of the United States.

Sadasivan and Sreenivasan(12) found that among well-known methods of determining phosphate availability in soils, the Truog method gave the highest percentage of extraction of soluble phosphate added to a certain Indian rice clay soil. The other extractants used in comparison with Truog's 0.002*N* sulphuric acid were: Dyer's 1 per cent citric acid, Frap's 0.2*N* nitric acid, Das's 1 per cent potassium carbonate, and Egner's calcium lactate-hydrochloric acid.

Anderson and Noble,(1) in comparing various quick chemical tests as employed independently by two analysts on different

[1] Read at the Fifth Philippine Science Convention, Manila, February 22, 1939.

[2] The writer wishes to express his appreciation of the helpful suggestions and criticisms given by Dr. Marcos M. Alicante, Chief of the Division of Soil Survey. Acknowledgment is also made of the writer's indebtedness to Mr. Rufino Isidro, of the same Division, in charge of the field experiments, for supplying the soil samples and the field data from the rice fertilizer experiments.

soils, found that the personal factor which caused poor agreement in results was greater in some cases than in others. Of the ten different procedures used for phosphorus availability, namely, the Simplex, the Emerson, the Sudbury, the Lamotte, the Hellige, the Indiana, the Hi-Lo-Fosfate, the Morgan, the Truog, and the alkaline-extraction methods, the Truog method was the only one that was not affected appreciably by the personal factor.

Several other investigators(4, 5, 7, 9, 11, et al.) working on the availability of phosphorus in soils in different parts of the United States have used the Truog test and obtained satisfactory results with it.

In view of this apparent accuracy and usefulness of the Truog test, it was considered worth applying on Philippine soils in which there is an imperative need for well-standardized rapid chemical tests as an aid in determining their fertilizer requirements.

EXPERIMENTAL

In this investigation the Truog test was carried out on composite soil samples from the experimental plots of several fertilizer experiments on rice, conducted in different provinces of Luzon. The object was to compare the response of rice to phosphatic fertilization or the field behavior of the soil, and the readily available phosphorus content of the soil on which the crop was grown.

The soil samples from the experimental plots were also analyzed for their pH values, total iron and aluminum oxides, calcium oxides, and phosphoric anhydride contents, to find if there is any relation between the chemical composition of soil and its readily available phosphorus content.

The reaction or the pH value of the soil must be known before the test is made, because the Truog method or any other method that makes use of an acid extractant does not apply to calcareous soils. The findings of Harper, Heck, Ford, and many other investigators show that the relative abundance of iron, aluminum, and calcium in the soil greatly affect the availability or solubility of soil phosphorus.

Four representative samples of each of different soil types where rice is grown were analyzed for their pH values, total CaO, total P_2O_5, and available phosphorus contents, for additional data on the relationship of the composition of the soil to its available phosphorus content. Reputedly fertile virgin

soils from different places in the Islands were also analyzed for comparison.

The method for determining the readily available phosphorus of soils as recommended by Truog was used with certain modifications. For a detailed discussion of the method the reader is referred to the paper of Truog and Meyer.(16) Briefly, the procedure employed in this investigation was as follows:

Two grams of the finely ground soil, passing a sieve with circular openings 0.5 mm in diameter, and 400 cc of 0.002*N* sulfuric acid, buffered to pH 3 with $(NH_4)_2SO_4$, were placed in a 750-ml Erlenmeyer flask and shaken intermittently for 30 minutes, with a total period of 15 minutes of actual shaking. After filtration, 50 cc of the clear filtrate were placed in a 200-cc Erlenmeyer flask. Two cc of ammonium molybdate-sulfuric acid solution were added, and the flask well shaken. Three drops of stannous chloride solution were then added, the flask again well shaken, and the resulting solution compared with a standard phosphate solution similarly treated. The comparison was made within a few minutes by the use of a Bausch and Lomb colorimeter, as the blue color of the reaction begins to fade after about 10 minutes. The results were then computed in parts of available phosphorus per million of oven-dry soil.

Because the method of shaking influences the amount of phosphate dissolved from soil by water, as reported by Hibbard,(8) the shaking of the samples, which was done by hand in this preliminary study, was done as uniformly as possible in all the determinations.

The pH values were determined by the use of the antimony and the glass electrodes. The chemical analyses for the other constituents were made according to the methods of the Association of Official Agricultural Chemists.(2)

RESULTS AND DISCUSSION

Table 1 shows the response of rice to phosphatic fertilization and the readily available phosphorus content of the soils on which the experiments were conducted. Since the soil samples were obtained after the harvest, the readily available phosphorus contents of the control plots might serve as those of the fertilized plots before treatment. Comparison may then be made on this basis.

TABLE 1.—*Response of rice to phosphatic fertilization and the influence of the readily available phosphorus content of soil on yield.*

Soil Lab. No.	Soil. Source.	Soil. Type.	Treatment (fertilizer formula).[a]	Average yield.	Increase in yield due to phosphatic fertilizer.	Available phosphorus.
				Cavans per Ha.	*Cavans per Ha.*	*P.p.m.*
E-22	Muñoz, Nueva Ecija	Maligaya silt loam	Control	22.2		3.4
E-23	do.	do.	20–0–0	23.1		3.6
E-24	do.	do.	20–20–0	38.9	15.8	7.8
E-31	Naic, Cavite	Guadalupe clay	Control	24.6		6.4
E-32	do.	do.	20–0–0	39.3		6.5
E-33	do.	do.	20–20–0	55.2	15.9	6.6
E-34	Tanza, Cavite	do.	Control	25.5		8.6
E-35	do.	do.	20–0–0	40.4		7.4
E-36	do.	do.	20–20–0	52.1	11.7	8.4
E-28	Tarlac, Tarlac	Luisita fine sandy loam	Control	27.8		25.6
E-29	do.	do.	20–0–0	35.5		27.7
E-30	do.	do.	20–20–0	56.9	21.4	28.8
E-25	San Manuel, Tarlac	San Manuel silt loam	Control	61.3		37.3
E-26	do.	do.	20–0–0	62.1		41.6
E-27	do.	do.	20–20–0	65.6	3.5	49.2

[a] The rate of application of fertilizer was 150 kilograms per hectare.

Table 1 shows that where the readily available phosphorus content was quite low, let us say, below 37.3 p.p.m., the increase in yield due to phosphatic fertilizer was relatively large compared with the increase in yield of soils quite high in available phosphorus, showing a positive correlation between crop response and the readily available phosphorus content of soils. If this relationship were inversely proportional, one would expect that the lower the available phosphorus content, the greater the increase in yield due to phosphatic fertilization of the soil. Table 1 shows that this would have been the case had not the soil from the fertilizer experiments in Tarlac, Tarlac Province (E28 to E30), given the highest increase in yield, although its initial readily available phosphorus content (E28) was not the lowest.

Another significant fact that one may get from the results of these experiments is that the addition of phosphatic fertilizers did not materially increase the readily available phosphorus content of all the soils except that of San Manuel, Tarlac Province (E25 to E27), which had the highest initial available phosphorus content. This fact may be explained by an investigation of the phosphorus-fixing power or capacity of the soils involved, which will be the subject of the next study. We may say here that,

because the soil from San Manuel, Tarlac Province, had a fairly high available phosphorus content (E25 to E27), its phosphorus-fixing capacity was low, as evidenced by the increase in readily available phosphorus content from 37.3 p.p.m. in E25 to 49.2 p.p.m. in E27.

The data on readily available phosphorus as checked by crop response to fertilization are, as yet, very meager, but more of these will be presented later, when the results of many more fertilizer experiments on rice, still in progress at the time of the writing of this report, are received by the writer.

For comparison, the results of other investigators on this subject in other countries, principally the United States, are presented here. As cited by Truog, McGeorge,(10) using 1 per cent citric acid for the extraction of Hawaiian sugar-cane soils, found the minimum limit of readily available phosphorus for good sugar-cane production to be approximately 17.5 p.p.m.; Dyer,(3) proposing the 1 per cent citric-acid method, set the minimum limit at approximately 44 p.p.m.; and Stoddart,(14) working with the N/5 nitric-acid method, set the limit at 66 p.p.m.

Using his method, Truog tentatively set the minimum limit of readily available phosphorus, for general farming under Wisconsin conditions, at 37.5 p.p.m. for the heavier, better soils, and at 25 p.p.m. for very sandy soils. He explained that

> Crops with a long growing period can get along with a lower supply than those with a shorter growing period, because the long growing period makes possible the utilization of a greater amount of the difficultly available phosphorus. A climate which makes possible a long growing period has a similar effect. As a consequence, fairly good crops of corn can apparently be produced in the South on soils whose readily available phosphorus supply would be entirely inadequate in the North.

Because of the various factors involved, such as crop requirement, climatic conditions, and type of soil, Truog suggested that for certain sections in the southern part of the United States, 10 to 15 p.p.m. of readily available phosphorus might suffice for a good crop of corn.

Harper found that of eighty-three soils with eight farm crops studied, very few soils produced a marked response from phosphorus fertilization when the easily soluble phosphorus was above 20 p.p.m. as determined by the Truog method.

According to Whitney and Gardner,(18) for calcareous soils, by their potassium carbonate extraction method, approximately

37 p.p.m. of available phosphorus may be regarded as the minimum for good crop production.

Table 2 gives the relation of the chemical composition of the soils from the rice fertilizer experiments to their readily available phosphorus contents. The results show that there was no significant variation in the pH values of the soil samples that could be correlated with the variation in easily available phosphorus contents. All the pH values obtained were within the soil reaction tolerance limit for rice, which is from pH 4.8 to pH 6.9 as reported by Weir.(17) Most of the pH values obtained were even within the optimum range of soil reaction for rice, which is from pH 5.5 to pH 6.1 as reported by the same author. But the determination of pH value was made on all the other soil samples just the same, because that was necessary for distinguishing a calcareous soil from a noncalcareous soil. As has been stated before, the Truog test applies only to noncalcareous soils.

TABLE 2.—*Relation of the chemical composition of soil to its readily available phosphorus content.*

Soil Lab. No.	pH value.	Fe_2O_3 and Al_2O_3.	Lime (CaO).	Phosphoric anhydride (P_2O_5).	Available phosphorus.
		Per cent.	*Per cent.*	*Per cent.*	*P. p. m.*
E-22	6.20	28.55	1.92	0.13	3.4
E-23	6.05	27.41	1.91	0.13	3.6
E-24	5.92	27.27	1.81	0.14	7.8
E-31	6.30	30.47	2.14	0.12	6.4
E-32	6.12	30.62	2.05	0.13	6.5
E-33	6.10	30.14	2.01	0.11	6.6
E-34	6.22	31.83	2.09	0.16	8.6
E-35	5.90	31.91	2.16	0.12	7.4
E-36	6.00	30.65	2.00	0.11	8.4
E-28	5.55	26.04	5.37	0.11	25.6
E-29	5.40	26.08	5.50	0.15	27.7
E-30	5.60	26.27	6.03	0.18	28.8
E-25	5.86	28.69	3.33	0.26	37.3
E-26	5.72	28.95	3.45	0.27	41.6
E-27	5.75	27.39	3.61	0.26	49.2

Ford and Heck, who made intensive studies on the subject of phosphate fixation in soils, showed that the presence of relatively large amounts of soluble or active calcium, iron, and aluminum compounds in the soil measures the chemical fixation of phosphorus in soils, which in turn limits the availability of soil phosphorus to plants. According to Heck, with sufficient active calcium and relatively small amounts of active iron and

aluminum in the soil, most of the phosphorus is fixed as tricalcium phosphate, which is slightly soluble in water but easily soluble in dilute acids and, therefore, readily available for plant growth. When active calcium is relatively low, and active iron and aluminum are relatively high in amount, phosphorus is fixed for the most part as difficultly available, except when the predominating compound formed is normal $AlPO_4$ which is moderately soluble in dilute acid solutions and, therefore, moderately available to plants. But fixation in the form of normal $AlPO_4$ generally takes place in very acid soils. When phosphorus is fixed as normal iron phosphate ($FePO_4$), as basic iron phosphate ($Fe_2(OH)_3PO_4$), or as basic aluminum phosphate ($Al_2(OH)_3PO_4$), its availability is very low.

Table 2 shows that there was not much variation in the iron and aluminum oxide contents of the soil samples from the rice fertilizer experiments. Soil sample E27 had 27.39 per cent of Fe_2O_3 and Al_2O_3, and soil sample E23 had 27.41 per cent of the same constituents, yet their readily available phosphorus contents differed greatly, showing that in this group of soils the Fe_2O_3 and Al_2O_3 contents did not constitute a factor in the availability of phosphorus.

The lime and phosphoric anhydride contents of the soil samples from the fertilizer experiments seemed to give a positive correlation with the available phosphorus contents. The groups or sets of samples E22 to E24, E31 to E33, and E34 to E36 had about the same amounts of lime content, around 2 per cent, while samples E28 to E30 had an average of about 5.5 per cent lime. Although their total P_2O_5 contents did not vary much, around 0.12 to 0.15 per cent on the average, their available phosphorus contents differed greatly. The relatively high available phosphorus content of one group was about three times the low available phosphorus content of each of the other groups. This shows that, with the total P_2O_5 contents remaining at about the same level, the higher the CaO content, the higher was the available phosphorus content of the soil.

Comparing soil samples E28 to E30 with samples E25 to E27 we find that both groups had relatively high CaO contents. The two groups differed in their total P_2O_5 contents, and the samples that had higher total P_2O_5 contents had higher available phosphorus contents.

Table 3 gives the average chemical analyses of some Philippine rice soils, and of some reputedly fertile virgin soils. Just

like the results presented in Table 2, the results given in Table 3 are arranged in the order of increasing readily available phosphorus contents, with the unclassified virgin soils grouped separately.

TABLE 3.—*Average chemical analyses of some Philippine rice soils and of some reputedly fertile virgin soils.*

Source (Province).	Type.	pH value.	Lime (CaO).	Phosphoric anhydride (P_2O_5).	Available phosphorus.
			Per cent.	*Per cent.*	*P.p.m.*
Rizal	Novaliches clay loam adobe	5.50	1.46	0.12	5.8
Pangasinan	Alaminos loam	6.04	1.24	0.09	6.9
Bulacan	Novaliches loam	5.95	1.06	0.12	10.4
Cavite	Guadalupe clay	6.66	2.33	0.19	10.7
Do	Tagaytay loam	5.92	1.76	0.27	12.4
Pangasinan	Bani clay	6.56	3.20	0.10	14.2
Nueva Ecija	Quingua silt loam	6.61	3.50	0.21	32.1
Ilocos Sur	Baybay sandy loam	6.64	4.85	0.18	32.8
Tarlac	Luisita fine sandy loam	6.12	5.17	0.15	39.2
Ilocos Sur	Sevilla clay loam	6.72	3.41	0.16	41.9
Tarlac	La Paz fine sandy loam	6.04	4.13	0.13	44.6
La Union	Baybay clay loam	6.68	3.48	0.26	45.8
Tarlac	San Manuel silt loam	6.02	3.84	0.16	47.4
Nueva Ecija	Bantog clay loam	6.42	2.43	0.22	48.0
Ilocos Sur	Baybay clay loam, deep phase	6.65	3.83	0.32	64.5
	UNCLASSIFIED VIRGIN SOILS				
Tayabas (Mount Banahao)		5.21	1.42	0.48	20.7
Davao (Mount Apo)		5.14	1.30	0.41	21.5
Tayabas (Mount San Cristobal)		5.64	4.20	0.46	28.7
Cotabato (Koronadal Valley)		6.18	4.63	0.26	64.7

In Table 3 we can see that again there was not much variation in the pH values of the different soil types which were under cultivation. However, it may be pointed out that, with the virgin soils studied, there seemed to be a positive correlation between pH values, CaO contents, and readily available phosphorus contents, although the variations in pH values were slight.

With the chemical composition of the different rice soils presented in Table 3, there was the same apparent positive correlation between CaO and readily available phosphorus contents, as that which existed among the results presented in Table 2. Beginning with the Quingua silt loam, which had an available phosphorus content of 32.1 p.p.m., all, with the ex-

ception of one (Bantog clay loam which had 2.43 per cent CaO), had relatively high CaO contents, above 3.41 per cent, and high available phosphorus contents, up to 64.5 p.p.m., which was that for Baybay clay loam, deep phase. In the case of the Bantog clay loam we might say that its fairly high total P_2O_5 content, 0.22 per cent, with a total CaO content not so low, gave it a fairly high available phosphorus content.

In the case of the virgin mountain soils, although the total P_2O_5 content was fairly high, the available phosphorus content was relatively low. The fairly low CaO contents of the Mount Banahao and the Mount Apo soils, 1.42 per cent and 1.30 per cent, respectively, might account for this. But what was more probable as the chief cause of this condition was that all these virgin mountain soils had very high organic matter contents (as shown by chemical analyses not included in this report) which held most of the phosphorus not in the available form. But through microbial or biological activities the phosphorus held in the organic matter portion of the soil gradually became available for plant growth.

SUMMARY

The Truog test for determining the readily available phosphorus of soils was made on soils where fertilizer experiments on rice were conducted. The meager results show that there was a positive correlation between crop response to phosphatic fertilization and the amount of readily available phosphorus in the soil; the lower the available phosphorus content of the soil, the greater was the increase in yield due to phosphatic fer tilization, with one exception.

Ninety soil samples from different parts of the Philippines, but mostly rice soils of Luzon, have been analyzed according to the Truog method. For some Philippine soil types, at least, 30 to 40 p.p.m. of available phosphorus may not be far from the minimum limit of available phosphorus that will suffice for a good crop of rice.

The results seem to indicate that, with the total P_2O_5 content of the soil remaining constant, the higher the CaO content, the higher was the readily available phosphorus content; and that, with the CaO content of the soil remaining constant, the higher the total P_2O_5 content, the higher was the readily available phosphorus content. Exceptions to these findings were virgin soils very rich in organic matter.

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DECOLORIZING CARBON AND SODIUM SILICATE FROM PHILIPPINE CARBONACEOUS RICE-HULL ASH

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Rice hulls are light in weight, neutral in odor, and have a slow combustibility. They are used for packing hygroscopic materials to prevent moisture absorption; for filtering and percolating; for insulation, the making of insect powder, and for various other purposes.

Burnt rice hulls have been suggested as raw material for making decolorizing carbon and sodium silicate (water glass).[1]

In the Philippines rice hulls usually serve as fuel in the rice mills. The black carbonaceous ash that remains after burning the hulls is now discarded as waste. If this carbonaceous ash can be profitably converted into decolorizing carbon and sodium silicate a new local industry can be established. Decolorizing carbon is used locally for refining sugar, and sodium silicate is employed in soap manufacture. Both of these products are also used industrially for numerous other purposes.

This paper is a continuation of our work on Philippine rice-mill products. It suggests new industries that may be developed in the Philippines from the byproducts of rice mills. In our first publication[2] we gave the results of our investigations on the nutritive value and preservation of rice bran and on the products that may be made from the bran. This report gives an account of our procedure for making, in one process, both decolorizing carbon and sodium silicate (water glass) from the carbonaceous ash obtained by burning Philippine rice hulls.

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It would seem advisable for the Government to establish, in or near Manila, a rice mill to be operated scientifically for the production of rice and rice-mill byproducts. The by-products will then be used as raw materials for making new things for which there is a demand. These new commodities will be processed in pilot plants to ascertain if it is feasible to produce them on a commercial scale. The polished rice that is milled could be sold to the Army to defray the expenses of operating the mill.

When paddy rice (palay) is milled in the Philippines for the preparation of white rice the byproducts are rice bran and rice hulls. The estimated yearly production of Philippine rice hulls is 567,342 tons.[3] A factory located near a rice-milling district would have an available supply of rice hulls from which industrial products may be made.

In Table 1 is given the analysis of rice hulls from two varieties of Philippine rice (ramai and macan).[4]

TABLE 1.—*Analysis of Philippine rice hulls.*

Constituent.	Variety of rice hulls.	
	Ramai.	Macan.
	Per cent.	*Per cent.*
Moisture	7.65	6.77
Fat (ether extract)	0.62	0.63
Protein	1.75	1.97
Crude fiber	34.97	38.92
Ash	22.29	21.69
Carbohydrates by difference	32.72	30.02
Total	100.00	100.00

As shown in Table 1, the hulls consist largely of crude fiber and also have a rather high ash content. According to Harding [5] the crude fiber yields a very pure cellulose. This substance serves as raw material for making numerous commercial products, such as paper, rayon, cellophane, and lacquers.

[3] Tom. cit., p. 19.
[4] Tom. cit., p. 21.
[5] Journ. Indus. Eng. Chem. 20 (1928) 310.

According to a recent announcement,[6] rayon made from the alpha cellulose of rice hulls is one of the latest Japanese industries:

> A $2,900,000 industry is being promoted in Tokyo with the object of producing rayon-making pulp from rice hulls, of which a practically unlimited supply is assured in Japan.
>
> The process which forms the basis of the new industry has been developed by the Tokyo Industrial Laboratory, a division of the Department of Commerce and Industry, in collaboration with the research institute of the South Manchuria Railway Company.
>
> Because Japan depends on imports for 250,000 out of 300,000 tons of rayon pulp annually consumed by the artificial silk industry, the supply of raw material from an entirely new source is expected considerably to benefit the textile industry as well as the farmers who are hard put to make a living from their scanty acres.
>
> Japan at present is among the world leaders in the production of rayon yarn. And Japan is the world's first rice grower. The annual crop averages 475 million bushels.

Rice hulls also contain pentosans which may be converted into furfural. This substance is used in making various kinds of synthetic resins.

When rice hulls are burned thoroughly so as to eliminate combustible carbonaceous matter, the ash that remains has a slightly grayish color and consists almost entirely of silica, as shown by our analysis (Table 2). On account of the high silica content this rice-hull ash, finely powdered, serves as a good polishing powder. It can also be employed in making polishing pastes and scouring soaps, and can serve as an ingredient in the manufacture of glass.

TABLE 2.—*Analysis of Philippine rice-hull ash, free of combustible carbonaceous matter.*

Constituent.	Per cent.
Silica oxide	95.38
Iron and alumina oxides	0.42
Calcium oxide	0.20
Magnesium oxide	0.52
Phosphorus as P_2O_5	0.57
Sodium and potassium oxides	2.20
Total	99.29

When rice hulls are burned as fuel in Philippine rice mills, the residue is usually a black carbonaceous ash. The carbon

[6] Science News Letter 32 No. 854 (1937) 120.

content of the ash depends upon the temperature of heating and the length of time the hulls are allowed to remain in the furnace.

In Table 3 is given the carbon content of eight samples of carbonaceous rice-hull ash obtained from the same rice mill. The percentage of carbon was determined by heating a weighed portion of the moisture-free ash in a muffle furnace to constant weight. As shown by the data the carbon content varied from 11.8 to 30.8 per cent, which shows that the rice hulls were not always burned under the same conditions.

TABLE 3.—*Carbon content of carbonaceous rice-hull ash.*

Sample.	Carbon. Per cent.
1	11.8
2	15.4
3	19.8
4	23.0
5	25.4
6	27.4
7	29.4
8	30.8

Based upon the analysis of rice-hull ash free of combustible carbonaceous matter (Table 2), the composition of rice-hull ash having different amounts of carbon was calculated. The results for samples containing 11.8, 15, 23.4 and 30.8 per cent carbon are presented in Table 4.

Ash free of combustible carbonaceous matter gave a total analysis (Table 2) of 99.39 per cent and a silica content of 96.98 per cent. If the ash contains 11.80 per cent carbon (Table 4, sample 1) then the silica content is calculated as shown below:

$$99.39 - 11.80 = 87.49$$
$$99.39 : 87.49 = 96.98 : X$$
$$X = 84.94\% \text{ silica}$$

The percentages of the other constituents (Table 4) were calculated in like manner.

The black carbonaceous ash obtained when rice hulls are burned as fuel consists mostly of silica and carbon (Table 4). Apparently this ash is similar to the silica black that Jacobson[1] prepared by heating a mixture of finely divided coal and siliceous material (diatomite). Concerning silica black Jacobson says:

> This black powder could not be separated into dark and light components like the original products by employing either air, water, or

[1] Journ. Indus. Eng. Chem. 26 (1934) 798.

TABLE 4.—*Composition of carbonaceous rice-hull ash containing different amounts of carbon.*[a]

Constituent.	Sample.			
	1	4	6	8
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Carbon	11.80	18.00	23.40	30.80
Silicon oxide (silica)	84.04	78.09	72.90	65.79
Iron and alumina oxides	0.37	0.34	0.32	0.29
Calcium oxide	0.18	0.16	0.15	0.14
Magnesium oxide	0.46	0.43	0.40	0.36
Phosphorus as P_2O_5	0.50	0.47	0.44	0.39
Sodium and potassium oxides	1.94	1.80	1.68	1.52
Total	99.29	99.29	99.29	99.29

[a] These data were calculated from the analysis of rice-hull ash, free of combustible carbonaceous matter (Table 2).

oil flotation. Neither could white or gray particles be recognized under a magnification of 560 diameters.

The mixture of coal and diatomite had changed into something that was no longer a mechanical mixture. This product the author called "silica black." . . .

This product, when made from coal and diatomite, or coal and precipitated silica, is a black siliceous material containing carbon in different proportions together with 4 to 7 per cent of a nonsiliceous residue composed mainly of iron and aluminum. When the silica black is obtained from coal and talc, however, the nonsiliceous residue amounts to more than 38 per cent.

X-ray photographs indicate that silica black is principally amorphous. However, a trace of a silicon carbide pattern is visible, showing that a small amount of crystalline silicon carbide must be present. The greater part of the carbon in the product is doubtless in the absorbed form, although a certain proportion may be represented as carbides of silicon, iron, and aluminum.

Silica black reduces metallic oxides at high temperatures and is a good agent for clarifying and decolorizing liquids. It also has a high oil absorption. Jacobson suggested various uses for it, such as a pigment for paints and printing inks; a carrier for insecticides and a support for nickel in the hydrogenation process.

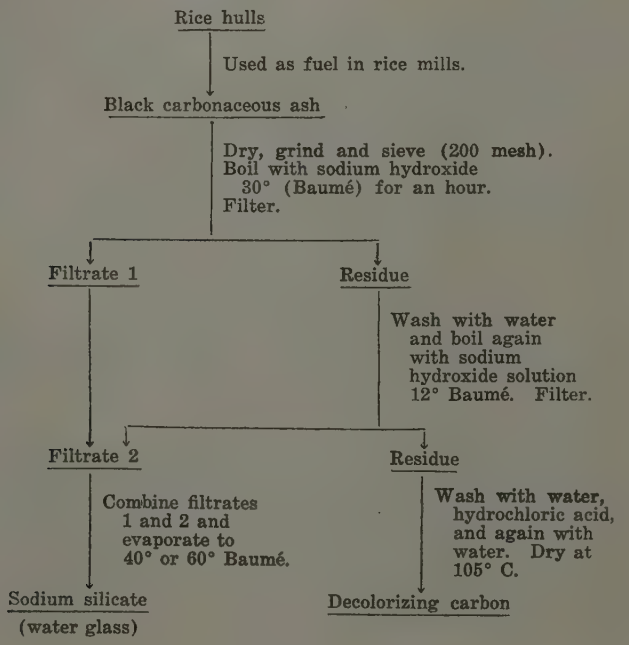
A sample of the finest grade (A) of silica black contained 18.14 per cent carbon, 75.56 per cent silica and 6.25 per cent of other constituents. By comparing this grade of silica black with a rice-hull ash having 18 per cent carbon (Table 4) it will be seen that these two products have somewhat the same composition (Table 5).

TABLE 5.—*Comparison of fine-grade silica black with carbonaceous rice-hull ash containing 18 per cent carbon.*

Constituent.	Silica black.	Carbonaceous rice-hull ash.
	Per cent.	*Per cent.*
Carbon	18.14	18.00
Silica	75.56	78.09
Other constituents	6.25	3.20
Total	99.95	99.29

EXPERIMENTAL PROCEDURE

A number of preliminary experiments were carried out to ascertain the best procedure for making in one process both decolorizing carbon and sodium silicate from carbonaceous rice-hull ash. These experiments consisted essentially in treating the ash with different concentrations of sodium hydroxide. Below is given an outline of the method we selected as the most appropriate procedure.



The carbonaceous ash obtained from the rice mills is first dried at 105° C., because the ash is often piled outside the mill where it is exposed to the weather. It is then ground sufficiently fine to pass a 200 mesh sieve. The dried and finely powdered carbonaceous ash is treated with sodium hydroxide solution having a concentration of 30° Bé. For each kilo of ash 2 liters of the alkali solution are used. The mixture is boiled about an hour to dissolve the soluble silicates after which it is filtered. Filtrate 1 from the carbon residue is set aside for the preparation of sodium silicate.

To remove most of the silicates the carbonaceous residue is washed with hot water. The residue is then placed in a suitable container. It is treated with a liter of sodium hydroxide solution (12° Bé.) After boiling for about one hour the hot solution is filtered. Filtrate 2 is combined with filtrate 1.

The black residue is washed with hot water, then with dilute hydrochloric acid to neutralize the alkali and again with water until the washings are no longer acidic. This decolorizing carbon is finally dried in an oven at 105° C. It is very efficient for decolorizing solutions.

The combined alkaline filtrates 1 and 2 from the carbonaceous ash are evaporated to a thick sirupy liquid (sodium silicate or water glass) having a concentration of 40° Baumé. This concentration is very suitable for sodium silicate intended for use as an ingredient in making soap. When the silicate is to be used as an adhesive or for other purposes the solution is evaporated still further to a concentration of 60° Baumé.

The color of the sodium silicate solution depends upon the kind of carbonaceous ash obtained from the rice hulls. For high-grade sodium silicate an ash containing a relatively small amount of carbon (less than 12 per cent) is preferable to one having a rather large amount, because the first gives a solution that is nearly colorless while the latter produces a yellowish-brown liquid. However, for soap making the colored sodium silicate is very satisfactory and gives a whitish cream-colored soap.

Data on carbonaceous rice-hull ash and the decolorizing carbon and sodium silicate made from it are given in Table 6. As shown by the data, treatment with alkali greatly reduces the ash content of the carbonaceous rice-hull ash by removing a large portion of the silica as soluble silicate which is converted into sodium silicate. The alkali also decomposes

some resinous constituents that are contained in the carbonaceous rice-hull ash. Analysis of the sodium silicate thus prepared is given in Table 11.

TABLE 6.—*Data on carbonaceous rice-hull ash and the decolorizing carbon and sodium silicate made from it.*[a]

Sample.	Carbonaceous rice-hull ash.		Decolorizing carbon.			Sodium silicate concentration, Baumé.[c]	
	Carbon.	Ash.	Carbon.	Ash.	Yield.[b]	40°	60°
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Grams.*	*Grams.*	*Grams.*
3	16.3	83.7	88.2	11.8	168.5	3,815	2,251
5	19.4	80.6	90.0	10.0	195.5	3,758	2,217
6	23.4	76.6	90.3	9.7	252.0	3,724	2,197
7	26.4	73.6	92.3	7.7	270.5	3,518	2,072

[a] The quantity of carbonaceous rice-hull ash used for each sample was 1,000 grams, dry weight.
[b] The yield of sodium silicate is given for a solution of 40° Baumé and also for a more concentrated solution of 60° Baumé.
[c] Analysis of the sodium silicate is given in Table 11.

Decolorizing carbon.—This product is also known as carbon black and as activated carbon. It is ordinarily obtained by the combustion of natural (hydrocarbon) gas or other carbonaceous materials, like nut shells. It is used in making numerous products; such as inks, polishes, pigments, carbon papers, black leather, insulating materials, rubber, gas masks, and for clarifying and decolorizing liquids.

Concerning the purification of water by carbon, Morrison[6] states:

> During the past six years the scope of usefulness of activated carbon has been much enlarged by its introduction into the field of water purification. At the present time between 800 and 1000 water purification plants depend upon activated carbon as the best means of insuring to the public palatable water at all times of the year. It is true that chlorine has for many years provided a germ-free water, but until the advent of activated carbon, many waters—although quite safe for drinking purposes—were at times unpalatable as compared with clear, spring water. The function of powdered, activated carbon is to absorb and remove from the water, impurities contained in the water or resulting from prior chemical treatment of water.

The samples of rice-hull decolorizing carbon recorded in Table 6 were tested in the laboratories of the Insular Sugar Refining Corporation at Mandaluyong, Rizal (near Manila). These tests were made to determine the carbon efficiency for

[6] Man In A Chemical World (1937) 38.

saccharine liquids. A fresh molasses of more than 80° Brix was used as the liquid to be decolorized and the results were recorded according to the Newburgh scale. For comparison these results were checked against the efficiency of a standard carbon and also suchar carbon. The data are recorded in Table 7.

TABLE 7.—*Carbon efficiency of decolorizing carbons.*

Carbon sample.	Carbon efficiency (Newburgh scale).
Standard	100.0
Suchar	165.0
Rice-hull No. 3	127.3
Rice-hull No. 5	127.3
Rice-hull No. 6	175.6
Rice-hull No. 7	83.3

With the exception of sample No. 7 the carbon efficiency of the rice-hull carbons was above the efficiency of the standard carbon. Sample 6 gave even a higher value than the Suchar sample.

The rice-hull decolorizing carbon, sample 7 (containing 92.3 per cent carbon), was obtained from a sample of carbonaceous rice-hull ash that was not burned very thoroughly or uniformly. It contained a quantity of only partly burned rice hulls. When this kind of carbonaceous rice-hull ash is treated with alkali to remove most of the ash the carbon that remains is not of very good quality.

If the furnace in the rice mill is handled properly, with modern temperature control, the rice hulls can very likely be burned uniformly to produce a carbonaceous rice-hull ash from which a good decolorizing carbon can be obtained.

To ascertain the decolorizing (carbon) efficiency of rice-hull carbon for vegetable oils a sample was checked against imported high-grade carbons, coconut oil being used as the liquid to be decolorized. The coconut oil gave an original color reading of 4.5 red and 27 yellow.

In determining the color of the coconut oil both before and after treatment with the decolorizing carbons we used a Wesson model, cabinet-type colorimeter made by the Emil Greiner Company. We also followed the procedure adopted by the Conference of Coconut Oil Manufacturers of the Philippines (1924).

All samples will be read to a yellow base to be determined by adding the two whole red units, within whose limits the sample falls, and multiplying same by 8.

The procedure for decolorizing the oil was as follows:

One hundred cubic centimeters of coconut oil were poured into a 250-cubic-centimeter Erlenmeyer flask. A definite amount of the decolorizing carbon was added. The mixture was placed on a steam bath for 15 minutes and shaken occasionally. It was then filtered several times until the filtrate was entirely clear. The clear oil was then cooled to room temperature and the color determined.

The quantities of decolorizing carbon used varied from 0.5 to 2 grams. The results are recorded in Table 8. As shown by the data these three carbons gave about the same results within experimental error. All of these carbons were thus found to be excellent agents for reducing the color of coconut oil.

TABLE 8.—*Decolorizing efficiency of rice-hull carbon and two imported carbons for decolorizing coconut oil.*[a]

Sample.	Quantity of carbon used for 100 cc coconut oil.	Color of oil.[b]	
		Red.	Yellow.
	Grams.		
Rice-hull carbon	0.5	1.6	9.0
	1.0	1.0	6.0
	1.5	0.6	4.0
	2.0	0.5	3.0
Standard carbon	0.5	1.7	9.0
	1.0	1.0	6.0
	1.5	0.6	4.0
	2.0	0.5	3.0
Suchar	0.5	1.4	9.0
	1.0	0.9	6.0
	1.5	0.5	4.0
	2.0	0.5	3.0

[a] The rice-hull carbon was sample 6 (Table 6) containing 90.3 per cent carbon.
[b] The coconut oil gave an original color reading of 4.5 red and 27 yellow.

The rice-hull carbon used in these color-reduction experiments with coconut oil was made by treating the black carbonaceous ash of rice hulls twice with sodium hydroxide (page 149). To ascertain the advisability of using a cheaper method for preparing the carbon in which less alkali is employed, we treated the carbonaceous rice-hull ash just once with sodium hydroxide (12° Baumé) according to the general procedure outlined on page 148. Data showing the amount of ash removed from the carbonaceous rice-hull ash by this treatment are given in Table 9.

TABLE 9.—*Composition of carbonaceous rice-hull ash before and after treatment with sodium hydroxide (12° Baumé).*

Sample	Carbonaceous rice-hull ash.			
	Before treatment with NaOH (12° Baumé).		After treatment with NaOH (12° Baumé).	
	Carbon.	Ash.	Carbon.	Ash.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
1	11.8	88.2	19.9	80.1
2	15.6	84.4	27.7	72.3
5-A	20.3	79.7	37.3	62.7
8	30.8	69.2	57.0	43.0

Treatment with sodium hydroxide (12° Baumé) removed only a small amount of ash from the carbonaceous rice-hull ash. Decolorizing carbon made in this manner contains a large amount of siliceous ash and is not efficient for decolorizing saccharine solutions. It is also not quite as good for reducing the color of coconut oil as the rice-hull carbon made

TABLE 10.—*Decolorizing efficiency of siliceous decolorizing carbons obtained by treating rice-hull ash only once with sodium hydroxide (12° Baumé).*[a]

Sample.	Carbon content of siliceous decolorizing carbon.	Quantity of siliceous decolorizing carbon used for 100 cc of coconut oil.	Color of oil.	
			Red.	Yellow.
		Grams.		
1	19.9	0.5	2.0	12.0
		1.0	1.8	9.0
		1.5	1.2	9.0
		2.0	1.1	9.0
2	27.7	0.5	2.0	12.0
		1.0	1.6	9.0
		1.5	1.1	9.0
		2.0	1.0	6.0
5-A	37.3	0.5	2.0	12.0
		1.0	1.6	9.0
		1.5	1.1	9.0
		2.0	1.0	6.0
8	57.0	0.5	2.0	12.0
		1.0	1.6	9.0
		1.5	1.1	9.0
		2.0	1.0	6.0

[a] Coconut oil was used as the agent to be decolorized. It gave an original color reading of 4 red and 24 yellow.

by treating carbonaceous rice-hull ash twice with sodium hydroxide (page 149). This is shown by comparing the data recorded in Tables 8 and 10.

Siliceous materials, like Fuller's earth, are used for clarifying oils and reducing the color. For ordinary commercial purposes these siliceous rice-hull carbons containing from 27.7 to 57 per cent carbon (Table 9) gave fairly satisfactory results for refining coconut oil. The color of the oil (Table 10) was reduced from a reading of 4 red and 24 yellow to 1 red and 6 yellow.

Sodium silicate (water glass).—Sodium silicate is commonly made by treating sand or other siliceous materials with sodium hydroxide. Sodium silicate has interesting properties which permit its use in various industries, particularly in the manufacture of soap. Aside from the special detergent properties which sodium silicate gives to soaps and washing powders, it has the added value of economy because of its low production cost.

Sodium silicate is used for preserving eggs by making the shells air-tight; as an addition to water to prevent the corrosion of water pipes. It is also employed as an adhesive in making paper boxes; as a binding agent for concrete roads and walls; for briquetting coal; and for other purposes.

Good accounts of the detergency and other properties of sodium silicate are given by Snell[9] and Vail.[10]

TABLE 11.—*Analysis of crude, refined, and imported sodium silicate.*

Constituent.	Sodium silicate, 40° Baumé.		
	Made from rice-hull ash.[a]		Imported.
	Crude.[b]	Refined.	
	Per cent.	*Per cent.*	*Per cent.*
Moisture	68.3	66.3	69.0
Silica	17.9	20.7	20.5
Sodium oxide	13.1	10.4	10.0

[a] The rice-hull ash employed in making the crude and refined sodium silicate contained 23.4 per cent carbon (Table 6).

[b] Commercial sodium hydroxide, which usually contains 1 to 2 per cent of chlorides and other salts, was used in making the crude sodium silicate. This sample of sodium silicate would, therefore, contain some chlorides and small amount of other salts not accounted for in the analysis.

[9] Journ. Ind. Eng. Chem. 25 (1933) 1240.
[10] Op. cit. 27 (1935) 888; 28 (1936) 294.

The composition of sodium silicate varies somewhat according to the method of preparation and the quality of the materials used in making it. As shown by the data, Table 11, the crude sodium silicate made from rice-hull ash, by the procedure given on page 149, contains more sodium oxide (12.1 per cent) than the imported sodium silicate (10 per cent). This kind of sodium silicate is good for making soaps, as the excess alkali aids in saponifying the fat.

For making adhesives and other products the excess alkali is not desirable as it tends to decompose them. By diluting the crude sodium silicate with water until the volume has been increased about 10 per cent and then heating it with rice-hull ash that has been burned until free of carbon, the excess alkali in the crude sodium silicate is neutralized. The refined product thus obtained is then evaporated to 40° Baumé. It has about the same composition as the imported sodium silicate except that it has a little less moisture.

Our analyses (Table 11) of imported sodium silicate and also the crude and refined sodium silicates, prepared from rice-hull ash, were made according to the methods given by Griffin.[11]

SUMMARY

When paddy rice (palay) is milled in the Philippines for the preparation of white rice the byproducts are rice bran and rice hulls. The estimated yearly production of Philippine rice hulls is 567,342 tons.

In the Philippines rice hulls usually serve as fuel in the rice mills. The residue after burning the hulls is generally a carbonaceous ash that has a black color and is now discarded as waste. Apparently this ash is similar to the silica black that Jacobson prepared by heating a mixture of finely divided coal and siliceous material.

This report gives an account of our procedure for making, in one process, both decolorizing carbon and sodium silicate (water glass) from the carbonaceous ash obtained by burning Philippine rice hulls.

Samples of the rice-hull decolorizing carbon gave for saccharine liquids a carbon efficiency greater than that of a standard carbon. One sample was even more efficient than suchar carbon.

[11] Technical Methods of Analysis (1927) 41.

The rice-hull decolorizing carbons were also found to be excellent for reducing the color of coconut oil.

Treatment of the carbonaceous rice-hull ash only once with sodium hydroxide (12° Baumé) gave a very siliceous rice-hull carbon. For ordinary commercial purposes these siliceous rice-hull carbons containing only 27.7 to 57 per cent carbon gave satisfactory results for reducing the color of coconut oil.

Crude sodium silicate, made from carbonaceous rice-hull ash by the method we employed, was found to contain about 2 per cent more alkali than imported sodium silicate. This kind is good for making soaps as the excess alkali aids in saponifying the fat.

By treating the crude sodium silicate with rice-hull ash (carbon free) the excess alkali is neutralized. This refined product had about the same composition as an imported sodium silicate.

FERN EVOLUTION IN ANTARCTICA

By E. B. Copeland
Of Berkeley, California

TWO TEXT FIGURES

This is a study in the reconstruction of the history of ferns by the interpretation of present geographic distribution.

The explanation of the present distribution of plants by their history is one of the comparatively few problems of the systematic botanist that have a wide popular appeal. This explanation is almost too easy, if the geologic history is known, but that is the case with only a small fraction of the living plants. Since what is demonstrably true of some plants of a region may well be true of others, the established history of a small part of the plants of Europe and North America gives us the probable history of a large part of the flora. Thus, if a plant,—say, *Osmunda bipinnata,*—be found now in the eastern United States and in eastern Asia, and its fossils are found in several northern lands, we recognize the present localities as remnants of a once far-northern range around the world, the present discontinuous distribution being the result of extermination by ice throughout the rest of its old range. And if another plant species is found in the same places, but no fossils are known, we do not hesitate to explain the discontinuity in the same manner. If a Japanese plant be nearly related to one of Atlantic North America, instead of being identical with it, the argument is the same; at least one of them has changed somewhat in the course of time.

That is, we construct the history of a plant, or group of plants, by interpreting the present distribution. In the absence of fossils, the argument has to take this direction. We are very familiar with this picture of the history of vegetation in the northern hemisphere. Our common American ferns are the common ferns of Europe, and it seems to us that this could hardly have been otherwise. For, with narrow gaps or none, we know that at a time, very recent, geologically speaking, the continents were connected by land with a climate favorable to our ferns.

We are far less familiar with the idea that any far-southern land might have been the common source of the vegetation of areas now completely disconnected. The comparative paucity of land in the South (text fig. 1), and the present total unfitness of antarctic land for vegetation, have tended to keep us from trying to apply to the South the ideas familiar to us with regard to the North. Still, it is nearly eighty years since J. D. Hooker [1] suggested such an explanation:

> The many bonds of affinity between the three southern Floras, the Antarctic,[2] Australian, and South African, indicate that these may all have been members of one great vegetation, which may once have covered as large a southern area as the European now does a Northern.

The most active exponent of this idea has been Skottsberg, who, in one of several papers on the subject,[3] listed many genera of flowering plants, in 49 families, represented in Antarctic America and New Zealand (or, a few, in Australia). Nearly a score of small families are distributed in a manner inexplicable on any other assumption. The evidence of small families forces itself on us, while we easily overlook that of large genera and families. Thus, in the case of *Grammitis*, with one manifestly Antarctic-bred species, and with about 120 species confined to the Tropics, the probably Antarctic origin of the genus has escaped suspicion; while *Todea*, with one far-southern species and no other species anywhere, has been conspicuous and accepted as strong evidence. A large family, even if of southern origin, cannot possibly be predominantly far-southern in present distribution, because tropical and northern species must outnumber the whole flora of Antarctic America, or even of New Zealand.

Besides vascular plants, the distribution of certain groups of mosses, worms, molluscs, crustaceans, and insects has been interpreted as indicating an origin farther south than where any such organisms now live.

As to the ferns, Christ [4] summed up the evidence to his date, and construed it better than have later writers, content to quote him inperfectly and add nothing:

> Noch bleibt eine hochinteressante Gruppe von Farnen zu erwähnen, welche man in dem Sinn antarktisch nennen kann, als sie zwar nicht boreal-alpin in Charakter, sondern gemässigte bis subtropische Anpassung zeigen,

[1] Flora of Tasmania 1 (1860). [2] Plant World 18 (1915) 142.
[3] That is, Antarctic American. [4] Geographie der Farne (1910) 248.

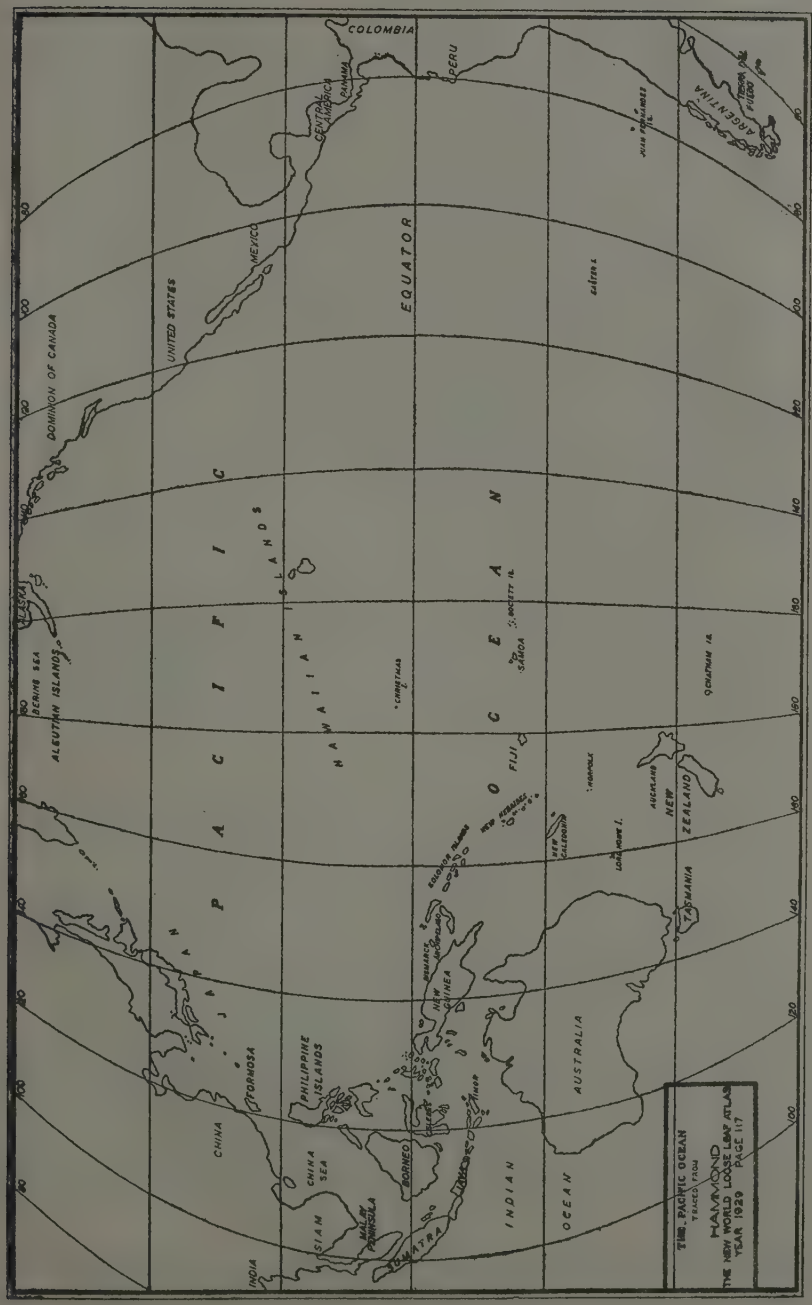


Fig. 1. The Pacific Ocean.

aber doch sich rund um den Südpol in tiefen Breiten sowohl der östlichen als westlichen Halbkugel ausdehnen. Sie sind nicht analog den arktischen Pflanzen, auch nicht den antarktischen Phanerogamen mit ihrem höchst charakteristischen Polsterhabitus, sondern nur dadurch verbunden, weil sie einen, wenn auch unterbrochenen, Kreis im tief ozeanischen Süden bilden.

Diese Arten gehören in erster Linie der neuseeländischen und überhaupt der australischen Flora an, streifen aber in die westliche Halbkugel oder doch bis S.-Afrika hinüber.

Dahin eine ganze Schar *Blechnum*: *australe, capense, tabulare, lanceolatum, attenuatum, penna marina, Polystichum capense* und *vestitum, Polypodium australe* und *Billardieri, Hymenophyllum ferrugineum, Asplenium obtusatum, Schizaea fistulosa.* . . . Auch *Hypolepis rugulosa,* . . . . Dahin aber muss auch gezählt werden das Genus *Dicksonia,* . .

Ebenso aber auch *Schizaea,* dieses zerfahrenste aller Genera, das aber, zwar zunächst um Neukaledonien gravitierend, doch offenbar vermöge seiner, S.-Afrika und S.-Amerika gleichmässig berührenden, Expansion entschieden auf ein Südzentrum hindeutet.

Diese Arten setzen ein solches, irgendwo im tiefen Süden gelegenes, tertiäres oder noch älteres Gebiet voraus, wo sie, genau wie so manche Blütenpflanzen gleichen Areals, den Ausgangspunkt ihrer radialen Wanderung haben. Dass dies Gebiet ein altes und warmes war bezeugt der ganze, zur Stammbildung geneigte und sehr frondose Aufbau der grossen und die Zartheit der kleineren dieser Farne . . .

Dieses nach anderen Kontinenten übergreifende Element der australischen Flora enthüllt uns die Herkunft dieser Flora überhaupt. Sie ist ein, auf den schmalen Areal Neuseelands, Tasmaniens und O.-Australiens mit ihren kleinen Satelliten, erhaltenes Relikt einer grösseren Südflora, die zur Tertiärzeit oder früher sich ausbildete, ausstrahlte und nun noch die ozeanischen Punkte bezetzt hält, und ihr klimatisch ihre Existenz sichern.

My own attention to this phenomenon came at the conclusion of a series of studies of the Hymenophyllaceæ, when the facts as to the present distribution of genera and species made me ascribe an Antarctic origin to the entire family. Now, the distribution of a dozen species might arouse our wonder, when they seemed to be isolated cases. But, once it was established that a fern family of several hundred species had this history, what had aroused wonder began to seem natural, and it appeared that it would now be wonderful if other ferns had not evolved in variety under the same favorable conditions as the Hymenophyllaceæ, and had not radiated from Antarctica at the same time as the filmy ferns. This is the more true, because dispersal over water seems likely to have been involved at all times, even if not always at all places, and the Hymenophyllaceæ are commonly believed to be disqualified for jumps to great

distances by having spores of briefer vitality than do most ferns. Moved by these considerations, I decided to subject the ferns as a whole to investigation from this point of view.

It must be observed in the beginning that the geological evidence, which fills out our picture of the past in the North, is largely wanting in the South. Not only is there no living fern in Antarctica; no fossil fern may be known there. Christ[5] reports fossils of *Cyathea, Blechnum,* and *Polypodium* from Seymour Island, from 64° south latitude; I believe they were found in Graham Land, but the difference is without interest. What geology really contributes to our understanding is summed up in italics in the Glaciology of Priestly and Wright (1922): "Glacial conditions have been the exception and not the rule in Antarctica"[6]; and "In the upper Oligocene or lower Miocene, once more a temperate to subtropical flora holds sway over some portion of the Antarctic Continent.[7] We would have had to postulate such conditions, as Christ did, from the facts of present distribution, but the argument is better when the geologist confirms it by direct evidence.

There are some general facts concerning ferns that may help to provide a foundation for the study of their history. More than nine thousand species are recognized today, in more than two hundred genera. As I divide them into families, using the latest Supplement to Christensen's Index, effective at the end of 1933, as to the numbers of genera and species, they are:

EUSPORANGIATE FERNS

Family.	Genera.	Species.
1. Ophioglossaceæ	4	92
2. Marattiaceæ	7	217

LEPTOSPORANGIATE FERNS (FILICES)

3. Osmundaceæ	3	20
4. Schizæaceæ	4	162
5. Gleicheniaceæ	2	120
6. Hymenophyllaceæ	4 (+2)	651 (+4)
7. Polypodiaceæ	182	8,034
8. Marsileaceæ	3	74
9. Salviniaceæ	2	16

Other especialists recognize more families. Thus, Christensen lists three others, which I include in Polypodiaceæ, and has since

[5] Op. cit., 330. [6] P. 44. [7] P. 446.

increased the number.[8] I do not know how many Bower might recognize, but certainly a much larger number. The question as to number of families is not related to the thesis of this paper; the families are listed here to give a general outline of fern classification, and to indicate the order in which they will be discussed. There are similar differences in practice as to the genera, but there is comparative uniformity as to the species. I will continue to use Christensen's figures, with few exceptions, as his Index is the nearest approximation to a common judgment of fern specialists.

However far back in geologic time the group of ferns may have originated, our living ferns are mostly a group of recent evolution; in fact, still actively evolving as a component of the world's vegetation. Although the ferns are a part of a larger group, the pteridophytes, in which seed plants are supposed to have originated, the Polypodiaceæ and Hymenophyllaceæ are families of recent and present time, just as truly as is any family of flowering plants. Their genera and species, in general, are still spreading; very few of them are commonly believed to have occupied a greater area, or been more numerous or more varied, at any previous time than they occupy and are today. Time is therefore one of the factors limiting their present range, although the necessity of suitable local conditions where the spores fall is a stronger limiting factor. Thus the total absence of Hymenophyllaceæ in our Pacific Northwest, where climatic conditions are ideal for many of them, must be explained by their not having been in northeastern Asia when the climate of Siberia and Alaska would have permitted them to spread to America. Against the scale of geologic time, this was the condition yesterday. Two species reached Saghalien and Ussuriland[9] (but the reporter mistook them for very old inhabitants), this morning, when the Behring bridge is temporarily closed.

Characteristically and in general, the ferns of today are plants of the humid Tropics, where, except in Africa, every moist mountain supports several hundred species. Four hundred thirty-seven species are known from Mount Kinabalu in Borneo, the forests of which are still far from being completely explored. With a distance from the equator, north and south, the number

[8] Verdoorn, Manual of Pteridology (1938).

[9] Kryshtofovich, A. Hymenophyllum and Trichomanes in Ussuriland. Sunyatsenia 3 (1935) 22.

of species, and their share in the vegetation, decrease, except in New Zealand and the subantarctic islands.

This great tropical fern flora might have evolved where it is, or farther north, or farther south. In the absence of evidence the simple assumption would be that it evolved where we find it, and where it is still in active evolution. We have no evidence that the Tropics as a whole were at any past time unfit for ferns; and the assumption that this has been the chief place of their evolution obviates the necessity of assuming and explaining migration in latitude. It is only when we open our eyes to 'anomalies' in present distribution that appeal to other places of evolution becomes necessary. Some of these anomalies have been mentioned, and more will be. I will show that such cases, in varying degree of emphasis, are far commoner than has been appreciated; that over a wide range of fern evolution what have seemed to be the anomalies really illustrate the rule.

As one leaves the equator, going north, the proportion of land to water around the globe increases (text fig. 2). All ferns are land, not marine, plants. Going south, the proportion of land decreases rapidly. A reasonable expectation would be that the north temperate zone would have many more fern species than the south temperate zone, except as differences in moisture might make the North relatively unfit for ferns; and that this would be true of ferns as a whole, and of each family and genus of tropical origin. Actually the land south of the equator is on the whole drier than that of the North, which would be expected to explain the relative paucity of southern ferns.

A richer development of a genus or family to the south in spite of this better present opportunity for wealth of fern species to the north, creates a strong case for a southern, rather than a tropical, origin of the group. The diversity of genera in the family or of species in the genus being greater in the South is a strong additional reason for postulating a southern origin. For, if diversity rather than numbers be the feature of difference, the presumption is that the species and genera which impress us as peculiar, divergent, or isolated have lagged behind in northward migration.

The most obvious evidence for southern origin is presented by the cases of widely discontinuous distribution already referred to, species and genera common to southern Chile and New Zealand, with Tasmania, the Cape, Juan Fernandez, and

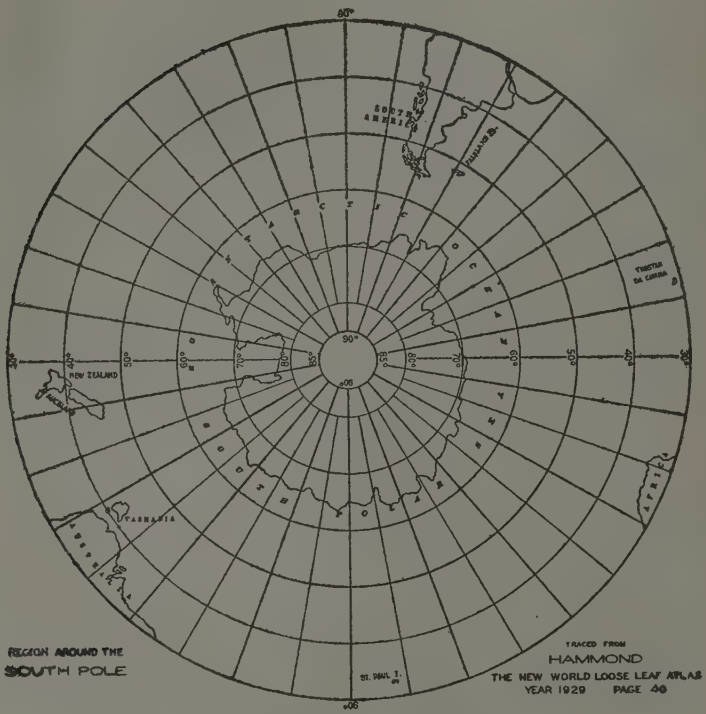


FIG. 2. The region around the South Pole.

the Falkland and other subantarctic islands as less common additional regions. Reiche [10] lists among the genera common to Chile and New Zealand: "Gleichenia, Alsophila, Dicksonia (auch J. F.), Trichomanes, Adiantum, Cheilanthes, Pellaea, Pteris, Asplenium, Polypodium, Gymnogramme, Notholaena, Schizaea (sehr ähnlich oder vielleicht identische Art), Ophioglossum, Botrychium, Lycopodium, Azolla." His list of identical species includes: "Hymenophyllum tunbridgense, ant. H. unilaterale, ant. H. rarum, Cystopteris fragilis, ant.[11] Lomaria alpina, Aspidium aculeatum, A. coriaceum."

The force of this kind of evidence is not always conceded. Thus, Diels [12] included members of groups which "at the present

[10] Grundzüge der Pflanzenverbreitung in Chile (1907) 301.

[11] "Ant." means antarctic. His *Aspidium* species are *Polystichum*.

[12] Essays in Geobotany (1935) 191: The Autochthonian flora [of Australia].

day, are distributed principally in the southern hemisphere, but it is impossible to infer that they originated in the south." Disclaiming the impossibility, I do so infer, as to the ferns; finally, as the evidence piles up, do so conclude, in many cases. The usual alternative is to picture these isolated groups as remnants of an old northern flora, exterminated in their old range by change of climate or by unendurable competition. Substitute southern for northern, and that is what they are. We know, then, that the postulated change of climate has occurred, and have no such explanation if we impute a northern origin.

The idea that plants can be driven to outposts where they are permitted to live on is a thoughtless transfer of an idea familiar and sound in the case of men. Competition can never drive a plant to a new place; it can only kill it off in its old place. Under very particular conditions, change in climate may result in migration. Thus, a glacier moving south across Canada would be associated with a change of climate in the United States, making it what the climate of Canada had been; and the change would take place slowly enough so that some Canadian plants would spread southward as the climate there became fit for them. Some plants may have been enabled to migrate from Antarctica as it chilled. Or these plants of Antarctica may have migrated previously, as plants are always doing, and then have been exterminated by cold in the land of their origin. There is no evidence whatever that any progressive change of climate, worldwide in its scope, has ever "driven" plants south in this manner, in Africa, into and across Australia, and in South America. When one explanation is integrally sound, and no other is even plausible, it is not worth while to be too timid in the acceptance of the one presented. On the same general ground, I am less cautious than were Hooker and Christ when I fix the Antarctic Continent as the source of the old far-southern flora; if it was another continent in the same place, whoever knows its name may substitute it.

In postulating the antarctic origin of any ferns, I do not have to have an opinion as to the various reasonable, unreasonable, and bizarre theories regarding land connections in geologic time. Fern spores are carried across water by the wind. Once the spores are taken up by the wind, ten miles of water is no barrier at all to their spread. One hundred miles of water may be one hundred times as great a barrier, because the spores must

hit a target, a suitable place to germinate and grow. Still, ferns spread readily across seas this wide. A thousand-mile stretch makes the obstacle again one hundred times as great as a matter of geometry; and other factors,—the limited vitality of the spores, the chance of falling or being washed out of the air, and the chance of very different climate at such a distance,—increase it materially. Ferns rarely jump a thousand miles of ocean. Still, a number of species are believed to have crossed the South Atlantic, and I believe that three genera, *Plagiogyria, Coniogramme,* and *Loxogramme,* have flown the North Pacific from Japan to Mexico, each in one single instance. It is not exactly impossible, then, that direct colonization has occurred between Chile, New Zealand, Tasmania, the Cape, and Tristan da Cunha, but the distances are great. The improbability that direct colonization has occurred in this case rests more on the small areas of take-off and target than on the distance itself. And the importance of the small areas is as much that they do not provide opportunity for the evolution of diversified floras, as that they do not provide an infinity of spores to be borne away, to come down where they may. *Plagiogyria, Coniogramme,* and *Loxogramme* had a continent on which to evolve and from which to take off, and another on which to land.

Family 1. Ophioglossaceæ.—The Ophioglossaceæ are regarded as the most primitive extant ferns, and therefore as very old. There are 2 large genera, *Ophioglossum* with 54 species, and *Botrychium* with 36 species. Both of these are cosmopolitan in distribution, and many of the species range very widely. There is some concentration of *Ophioglossum* species in the South, but no marked center of evolution and dispersal. A single species of *Botrychium, B. australe,* known only from Tasmania, Australia, New Zealand, and Argentina, may be regarded as an obvious immigrant from the south. On the whole, the distribution of both genera indicates the great age ascribed to them on other grounds. We may suppose that they were represented in Antarctica during the last period of fern luxuriance there, and that some emigrants thence still survive; but that another and probably larger element in both genera survives from a fern flora living elsewhere at the same time.

Family 2. Marattiaceæ.—Marattiaceæ, though distinctly primitive in some of its characters, has evidently undergone vigorous evolution in comparatively recent time, and is still active. It is almost wholly tropical in present distribution, confined to

moist places because of the size or fleshy nature of the leaves. Only one genus, *Marattia,* with 56 species, is common to the Oriental and American Tropics, and is confined to them except for one species in New Zealand. In such cases, of which we will find many, the view has always been that the genus reached New Zealand from the Tropics. However, the species of the old and new worlds must have had somewhere, as well as at some time, a common source. In many of the cases just referred to, we will find other reasons for regarding Antarctica as the common ancestral land. Conforming the idea to the patterns thus established, I suppose that the existing species of *Marattia* had common ancestors in Antarctica, and that the surviving New Zealand species is a remnant, marking the path of migration to New Guinea and Malaya. *Angiopteris,* with 120 species, ranges from Pitcairn Island to Réunion and Japan. Three small related genera in southeastern Asia and Malaya suggest a very old center of evolution in that region. *Danaea,* with 32 species, is confined to the American Tropics. All of these must have had a common origin; but this may well have been too long ago for anything in the present distribution to provide any clue to the region.

Family 3. Osmundaceæ.—By general agreement, these are the most primitive members of the order Filices. They must then be a very old stock, and there is abundant fossil evidence that this is so. There survive 3 genera, with some 20 recognized species, of which 13 are in *Osmunda.* They are so scattered over the world as to give no hint of any particular place of origin.

The other two genera have a different history. *Todea* was described in South Africa, and the same species is found in New Zealand and Tasmania, with a variety in Australia; that is its entire range. Only Chile is wanting to give it the whole range of the most typically limited migrant from Antarctica. Of course, it had a still older history, leading back to a common origin with *Osmunda,* in some region not to be guessed at. But, as an element of the vegetation of today, one need not hesitate to ascribe to it an antarctic origin.

Leptopteris, the third genus, has seven not too distinct species: 2 in New Zealand, 1 on Lord Howe Island, 1 in New South Wales and New Caledonia, 1 in the Solomon Islands, 1 in Polynesia and New Guinea, and 1 in New Guinea only. It is to be regarded as an antarctic genus, migrant to and through New

Zealand, undergoing specific differentiation as it went. Its nearest relative is *Todea*, and it requires little imagination to postulate their evolution as distinct genera in Antarctica.

Family 4. Schizæaceæ.—The Schizæaceæ and the Gleicheniceæ are coordinate groups, intermediate between the lower Osmundaceæ and highest, most modern ferns. The Schizæaceæ include 4 genera, with 162 species.

Schizaea includes 29 species, in three subgenera that may be regarded as closely related genera. One species I do not place. The others, listed in full to show the distribution completely, follow:

Subgenus *Euschizaea*:

S. fistulosa Labill.	New Zealand, Auckland Island, Tasmania, New Caledonia, Antarctic America, Falkland Islands.
S. bifida Willd.	New Zealand, Australia.
S. pectinata (L.) Sw.	South Africa, Madagascar, Santa Helena.
S. tenella Kaulf.	South Africa.
S. malaccana Baker.	Malaya, Burma.
S. Hallieri Richter.	Borneo.
S. robusta Baker.	Hawaii.
S. incurvata Schkuhr.	Tropical South America.
S. pusilla Pursh.	New Jersey to Newfoundland.

Subgenus *Lophidium:*

S. dichotoma (L.) Smith.	New Zealand, Polynesia to Madagascar.
S. rupestris R. Br.	Australia.
S. elegans (Vahl) Sw.	Tropical America.
S. poeppigiana Sturm.	Do.
S. fluminensis Miers.	Tropical South America.
S. pacificans Mart.	Brazil.
S. Sprucei Hooker.	Amazon.

Subgenus *Actinostachys*:

S. digitata (L.) Sw.	Polynesia to Madagascar.
S. Balansae Fourn.	New Caledonia.
S. plana Fourn.	Do.
S. tenuis Fourn.	Do.
S. intermedia Mett.	Do.
S. laevigata Mett.	Do.
S. Biroi Richter.	New Guinea.
S. spirophylla Troll.	Amboyna.
S. pennula Sw.	Tropical America.
S. penicellata H. B. W.	Tropical South America.
S. orbicularis (Baker) C. Chr.	Colombia.
S. Germani (Fée) Prantl.	West Indies, Florida.

S. fistulosa has the range most positively indicative of Antarctic origin, occurring in all major far-southern regions except South Africa, where it is represented by *S. tenella,* and with no northerly range except to New Caledonia. Still Richter [13] in a careful study of the subgenus, and recognizing this species as the approximate parent, conceived it to be New Caledonian in origin and to have migrated thence south to Tasmania, east to Chile, and west to Madagascar. Better than Richter's was Christ's earlier statement.[14]

South Africa, besides being farther from Antarctica by a critically wide margin than are Cape Horn and New Zealand, and practically without interplaced islands, is not now a favorable place for ferns. Madagascar, not so much farther north, is favorable,—it has more fern species than are now known from the whole African continent. Because it seems to be here only that fern spores carried northward in this region would now find a fair chance to effect colonization, I regard Madagascar as having been so colonized, either directly or by way of the continent, if the Cape was at the critical time a land more fit for ferns. Ferns have reached Madagascar from various directions, but Antarctica must be recognized as one likely source of them. This is important here because the other two subgenera of *Schizaea* occur in Madagascar.

Each of the other subgenera has one species ranging from Polynesia to Madagascar, and the other species either confined to New Caledonia or mostly South American.

The genus as a whole and all its subgenera are now chiefly tropical, only one species falling, in a tropical-storm path, far to the North. But the species of *Lophidium* and of *Actinostachys* in the two hemispheres (eastern and western) must have had somewhere a common origin. This may reasonably have been where the three subgenera had in turn their common source; and *Euschizaea* is patently antarctic in origin. Also, as to the other two subgenera, the old-world range is on the whole south-tropical, for the Tropic of Capricorn crosses Madagascar and just misses New Caledonia. The fern flora of New Caledonia

[13] Meded. Rijks Herb. Leiden No. 28 (1916) 4.

[14] Geographie der Farne (1910) 157: Um so klarer ist es, dass wir hier ein Genus haben, dessen Verbreitung rein historischen Ursachen zuzuschreiben ist, das einem alten Ausgangspunkt in der S.-Hemisphäre entstammt, und das heute in einem völlig fragmentären Areal vorliegt; immerhin so, dass im Norden von S.-Amerika und um Neucaledonien sich sekundäre Formenkreise gebildet haben.

has been regarded as an eastern outpost of the Malayan, but it now appears to be austral (New Zealand) in origin, and that migration has been westward rather than toward the East. The storm track leads westward on both sides of the equator.

Species of *Lygodium*:

L. articulatum A. Rich.	New Zealand.
L. circinnatum (Burm.) Sw.	Queensland to India.
L. flexuosum (L.) Sw.	Queensland to China.
L. japonicum (Thunb.) Sw.	Queensland to China, Japan.
L. hians Fourn.	New Caledonia.
L. scandens (L.) Sw.	Polynesia to Africa.
L. reticulatum Schkuhr.	Polynesia, Australia.
L. trifurcatum Baker.	Melanesia, Banka.
L. dimorphum Copel.	New Guinea.
L. Kingii Copel.	Do.
L. Moszkowskyi Brause.	Do.
L. Versteegii Christ.	New Guinea, Luzon.
L. digitatum Presl.	Philippines, Malacca.
L. semihastatum Desv.	Philippines, Mariannes.
L. basilanicum Christ.	Philippines.
L. Matthewi Copel.	Do.
L. Merrillii Copel.	Do.
L. Mearnsii Copel.	Do.
L. Teysmannii v.A.v.R.	Pulo Pisang.
L. borneense v.A.v.R.	Borneo.
L. derivatum v.A.v.R.	Lingga.
L. polystachyum Wall.	Malacca, Tenasserim.
L. salicifolium Presl.	India.
L. conforme C. Chr.	Tonkin, Hongkong.
L. subareolatum Christ.	China.
L. lanceolatum Desv.	Madagascar, Comores, East Africa.
L. Boivini Kuhn.	Madagascar, Comores, East and South Africa.
L. Kerstenii Kuhn.	Madagascar, Comores, East Africa.
L. Brycei Baker.	Rhodesia.
L. Smithianum Presl.	East Tropical Africa.
L. volubile Sw.	Tropical America.
L. polymorphum (Cav.) H. B. K.	Do.
L. mexicanum Presl.	Do.
L. heterodoxum Kunze.	Venezuela to Mexico.
L. radiatum Prantl.	Colombia to Guatemala.
L. micans Sturm.	Guiana, West Indies.
L. oligostachyum (Willd.). Desv.	West Indies.
L. cubense H. B. K.	Cuba.
L. palmatum (Bernh.) Sw.	Atlantic United States.

As the species of *Lygodium* are presented in the foregoing list, they present a clear picture of a genus which, although now almost wholly tropical, once emigrated from Antarctica by all

three of the great possible routes. Although no species survive in far-southern America, no other common source of the American and old-world species can be supported with any plausibility. The one isolated northern species may be regarded, like *Schizaea pusilla*, as a plant picked up where *Lygodium* thrives, but deposited far from its fellowship by one of the tropical hurricanes which at intervals sweep up the Atlantic coast of the United States; or it may be a sole survivor of a flora antedating the Antarctic emigration.

The species of *Lygodium* form natural groups, but there is no such uniform agreement about these as in the case of *Schizaea*. Whatever character serves as the basis of primary classification, the resulting groups are well represented in both eastern and western hemispheres. Prantl, followed by Diels in Die Natürlichen Pflanzenfamilien, recognized three major groups: (1) *Palmata*, including *L. articulatum* (New Zealand), *L. circinnatum* (Queensland to Ceylon), and *L. radiatum* (Colombia to Guatemala); (2) *Volubilia*, including *L. scandens* (with wide paleotropic range), *L. lanceolatum* (Madagascar, and other localities), and *L. volubile* (tropical America); (3) *Flexuosa*, including *L. flexuosum* (Queensland to China), *L. Karstenii* (Madagascar, and other localities), and *L. polymorphum* (throughout tropical America).

Thus the argument as to the origin of the genus applies with the same force to every major group of species. The groups existed in Antarctica before the dispersal from that region.

Fossil *Lygodium* is reported from Europe in the Cretaceous, Eocene, and Miocene. I do not guess at the subsequent history of these old European Lygodia; no plant in the genus survives in or near Europe. *Lygodium* as it exists today is more than probably of Antarctic origin.

Mohria, whether one polymorphous species or several similar species, is found in Africa from the Cape to the equator, in Madagascar and in the Mascarenes. It might be autochthonous in that region; but it is simpler to regard it as Antarctic; since it must have had a common source with the other genera of its family, we ascribe their evolution to Antarctica, and can regard Antarctica as the normal source of a South African plant.

In *Anemia* 91 species are recognized, of which 86 are American, reaching beyond the Tropics, with 1 species each in Florida and Texas, and several in southern Brazil. The others are one

in South America and Madagascar, 3 endemic in Madagascar, and one in Abyssinia and India. This distribution has served as a remarkable illustration of the connection of the floras of South America and eastern Africa and Madagascar. It would be as easy to believe that the connection was by way of Antarctica, as that it was direct; and after it becomes probable that the other genera of the family were once Antarctic, the necessity of a common source of all the genera makes the distribution of *Anemia* serve as additional evidence. The genus has undergone very active recent evolution in South America.

Considering that the distribution of all the genera, and all the species of the family with one possible exception, can be explained by imputing an Antarctic origin to the family, and that the distribution of *Anemia* and *Lygodium* and of their subgenera or groups of species fairly demonstrates this origin, we may, with more than reasonable confidence, regard the extant Schizæaceæ collectively as migrants from Antarctica.

Family 5. Gleicheniaceæ.—Gleicheniaceæ consists of 2 genera (or better, 5), and includes 120 species, of which the Index places 1 in *Stromatopteris*, and 119 in *Gleichenia*. The latter fall into 4 subgenera, to which I prefer to give generic rank, as Christensen does in the latest expression of his views. The argument is the same, whatever the rank given to the groups.

Gleichenia in the stricter sense (9 species), *Platyzoma* (1 species), and *Stromatopteris* constitute a closely related group, small enough so that the species may be listed, to show their positively southern character:

Gleichenia polypodioides Sw.	South Africa, Madagascar, Amsterdam Island.
G. circinnata Sw.	New Zealand, Tasmania, Australia, New Caledonia, Borneo, Malacca.
G. dicarpa R. Br.	Tasmania, Australia, New Caledonia.
G. alpina R. Br.	New Zealand, Tasmania, Samoa.
G. rupestris R. Br.	Australia, New Caledonia.
G. vulcanica Blume.	Malaya.
G. peltophora Copel.	Mindanao.
G. madagascariensis C. Chr.	Madagascar.
G. Boryi Kunze.	Réunion.
Platyzoma microphyllum R. Br.	Australia.
Stromatopteris moniliformis Mett.	New Caledonia.

The Antarctic origin of this group of genera is too obviously probable to require any argument.

The other 2 genera are *Dicranopteris* with a few species, and *Sticherus* with nearly one hundred. *Dicranopteris* is typified by *D. linearis* (Burm.) Und., common throughout the Oriental Tropics and in New Zealand. Its American vicar is *D. pectinata* (Willd.) Und. Once the idea is familiar, it is easy to recognize a genus in the Tropics of both hemispheres, and surviving as far south as New Zealand, as being Antarctic in origin.

The type of *Sticherus* is the Malayan *S. laevigata* (Willd.) Presl. There are many species in all tropical lands, and at least two range northward to Japan. The southern character of the genus is strongly emphasized by the presence of 5 species in southern Chile, 1 of them in the Falkland Islands and 1 in Juan Fernandez; 3 in New Zealand, 1 of them and 1 other in Tasmania; 1 in South Africa, and 1 in Madagascar, the Seychelles, and the Mascarenes. The northward distribution is unbroken along every path of migration into the Tropics. The Chilean, New Zealand, and South African stragglers along the way point out more than sufficiently the common source, still farther south, of the many species of the Tropics, Oriental and American.

Summing up: All genera of Gleicheniaceæ having more than one species give individual evidence of Antarctic origin, and the monotypic genera are found where an Antarctic origin is easy to assume. As a component of the living flora, this family is entirely Antarctic at some stage of its history.

Family 6. Hymenophyllaceæ.—I have presented the evidence concerning the Hymenophyllaceæ elsewhere [15] and it will suffice to summarize it here. I recognize 32 genera, in contrast with the 4 (and 651 species) in the Index. Of these, *Hymenophyllum, Meringium, Mecodium, Sphaerocionium, Vandenboschia, Selenodesmium,* and *Didymoglossum* occur in both hemispheres (eastern and western), and all have far-southern extant species. There survive also, in the far South only, *Cardiomanes, Polyphlebium,* and *Apteropteris* in New Zealand, and *Serpyllopsis, Hymenoglossum,* and *Leptocionium* in subantarctic America. There are other genera in only one hemisphere, with their appropriate southern representatives. And the genera confined to the Tropics are regarded as derived from specified genera of evident southern origin.

[15] Philip. Journ. Sci. 67 (1938) 1.

These filmy ferns are particularly dependent upon humidity. If humid regions only be considered, the number of their species in proportion to all fern species increases steadily with south latitude, from less than one in one hundred north of the Tropic of Cancer to one in twelve in the Tropics, one in five in New Zealand, and one in three in Stewart Island. In Juan Fernandez they are not quite one in three, but may exceed half in the Falkland Islands. This seems to suggest that in old Antarctica the Hymenophyllaceæ were fairly comparable in numbers with the Polypodiaceæ. The latter also are largely of the same origin, but the Hymenophyllaceæ have fallen behind, for two reasons: They are relatively incapable migrants; and have been relatively inactive in recent evolution in the Tropics.

No other plant family of its size and diversity is quite so conspicuously Antarctic in origin as this one.

Family 7. Polypodiaceæ.—The families so far discussed have been evident phyletic entities, "natural families." The components of each could therefore be assumed to have a common ancestry and a specific common place of origin. The Polypodiaceæ, as usually limited, excluding *Dicksonia, Cyathea,* and *Matonia* (if these are excluded, so should be *Plagiogyria*), are not a natural family, though they are an easily defined one. Quite certainly, their genera represent three freely branched phyletic lines of distinct outside origin, related respectively to *Dicksonia, Cyathea,* and *Matonia,* usually treated as representing two or three distinct families. In an attempt to make the family natural, that is, to make it have a single outside ancestral source, I made it include the genera mentioned; and may not even then have succeeded. Each of these genera has a large number of related genera, "cousins, brothers, descendants, and nephews." Not all Polypodiaceæ fall evidently into any of these three groups, but most of them do. Not knowing a common ancestor of the three, I cannot try to assign it a place in geography; and at any rate, such a common ancestor would have to be sought farther back in time than I suppose the major evolution of ferns in Antarctica, and the migration thence to have occurred. The three will therefore have to be considered in succession.

The Polypodiaceæ, whatever the scope of the family, are regarded as the "highest," most modern ferns, those of most recent evolution. As to many genera confined to their several limited regions, this is altogether true; they evolved where they are, so recently that the time they have had limits their range. As to the family as a whole, it has been assumed to have passed

its evolution through stages to which those of the Schizæaceæ and Gleicheniaceæ correspond. If this meant that they were descended from these families, we could conclude directly that they must have a common source in geography, that the Polypodiaceæ collectively are also of probable Antarctic origin. However, the sounder opinion is that a common ancestor of the families lived so long ago that present distribution can give us no clue to the region it inhabited, if, indeed, there was any one definable region. This leaves us to test *Dicksonia* and other primitive Polypodiaceæ as we did *Schizaea,* to see if the present distribution of the species indicates a definite common source. By this time we are justified, however, in approaching the problem with some prejudice; because we know now that evolution in Antarctica and migration thence are responsible for the distribution of many ferns, and that the conditions responsible in their cases may well have operated similarly with those still to be considered.

In *Dicksonia* the distribution of the species is:

New Zealand, 3; Tasmania and Australia, 1; New South Wales and Queensland, 1; New Caledonia, 3; Fiji and Samoa, 1; New Guinea, 4; Malaya, 1; in all, 14 radiant along the New Zealand–Tasmania path.

Juan Fernandez, 1; Peru, 2; Equador and Brazil, 1; Colombia and Central America, 3; Mexico, 1; in all, 8 along the Andean path.

Saint Helena, 1.

This distribution can by this time speak for itself.

Genera related to *Dicksonia* and about equally advanced in a morphological sense are *Thyrsopteris* and *Cibotium. Thyrsopteris* has one species, endemic, on Juan Fernandez. As Juan Fernandez can hardly have evolved so peculiar a fern, its most reasonable origin, as a Juan Fernandez fern, is Antarctica, whether directly or through southern Chile. European fossils have been referred to this genus, but Juan Fernandez was not colonized from Europe,—before Robinson Crusoe.

Cibotium has 3 species in Malaya and China, 4 in Hawaii, and 5 in Mexico and Central America. One will not hastily use a genus without a species south of the Tropics as evidence of Antarctic origin. Still, the strangely discontinuous distribution must have an explanation, and the fern flora of Hawaii is almost wholly of southern origin. It may be that the story of *Cibotium* began too long ago for its scene to be guessed at; but if we do try to determine its history from its distribution,

the most reasonable theory is that it reached its present isolated stations from the South.

Culcita seems to stand between *Dicksonia* and *Dennstaedtia*. It has 1 species in Australia, 2 in western Polynesia, 3 in Malaya including Luzon, 1 in Formosa, 1 in tropical America, and 1 in the Atlantic Islands. It has lost its far-southern connections, but its discontinuous distribution, taken with its affinity to *Dicksonia*, indicate such an origin.

The preceding 4 genera are sometimes treated as belonging in a separate family, Dicksoniaceæ. However, *Dennstaedtia*, clearly related to *Culcita*, is always included in Polypodiaceæ. It is a genus of 70 species; and *Microlepia*, which blends with it, has 45. Nearly all are tropical. One species is in the United States, and several reach Japan, but these are not so related as to suggest an old northern connection. In the other direction, *D. glauca* (Cav.) C. Chr. ranges from lower Chile to Bolivia; *D. davallioides* (R. Br.) Moore is in Tasmania and Australia; *M. Pinckneyi* (Col.) C. Chr. is in New Zealand; and *M. madagascariensis* is where its name indicates. *M. Speluncae* (L.) Moore, in both New Zealand and Madagascar, has spread over all tropical lands. *Dennstaedtia* is reported by Berry [16] in the upper cretaceous of Patagonia. Aside from the fact that their relatives suggest a southern origin, this is the simplest explanation of the range of these 2 genera. Their recent evolution in the Tropics has been active.

Hypolepis and *Paesia* are so near to one group of species in *Dennstaedtia* that my Bagobo botanist friend Angat gave one name to the three, though he had another name for another *Dennstaedtia*, and accurately distinguished by name an amazing number of ferns. *Hypolepis* has 45 to 50 species, half of them in the American Tropics, without surviving Chilean representatives. In the old world the paths from the South are still well marked. South Africa has 2 species, one of them reaching the Mascarenes and Fernando Po; another is in Abyssinia; and *H. punctata* is found on islands on both sides of Africa. New Zealand has 6 species, of which *H. dicksonioides* (Bory) Hooker reaches to Australia and Polynesia; *H. rugosula* (Lab.) J. Sm., farther into the Tropics; *H. tenuifolia* (Forster) Bernh., to China; and *H. punctata* (Thunb.) Mett., to Japan. The path of migration remains peopled by more local species,—*H. elegans* Carr. on Lord Howe, Aneityum, and Fiji, others in New Cale-

[16] Science 86 (1937) 221.

donia, New Guinea, Malaya, the Philippines, and Formosa. One species is endemic in Hawaii. *Hypolepis* conforms to the picture of an old Antarctic genus now at home chiefly in the Tropics, but with two of the paths from the South still occupied.

Paesia has 1 New Zealand species, said to be in New Guinea also, 1 in New Caledonia, 1 endemic in New Guinea, 2 in the Philippines, 1 in Sumatra, 2 in Tahiti, and 4 in America, from Peru to Jamaica. On its small scale, the story is the same as that of *Hypolepis*.

Nearly enough related to *Paesia* to have sometimes been united with it is *Pteridium*, the bracken, one of the most cosmopolitan ferns. It occupies paths of migration from the South, and must have lived in Antarctica, but that may or may not have much to do with its present distribution. Another relative, *Histiopteris*, has a few local derived species and one, *H. incisa* (Thunb.) Ag., is pantropic in present distribution, but also in so many far-southern lands that its Antarctic origin is hardly questionable. Another relative is *Lonchitis*, including *Anisosorus* of the Index. It has 11 species: 5 in the American Tropics and 6 in Africa, especially developed in the South and in Madagascar. It may evidently be of Antarctic origin, and is best so regarded because it must share its origin with its relatives.

We come now to *Pteris*, a genus of 269 recognized species. As is true of all really large genera, its great wealth of species is in the Tropics. The species with reticulate venation constitute a subgenus, *Litobrochia*, nearly related to *Lonchitis*, which I regard as the more primitive element of the genus. *Litobrochia* has two New Zealand species, one endemic, the other, *P. comans* Forster, being found also in Tasmania and Juan Fernandez, as well as in Polynesia. It thus survives to mark the paths of migration into the Tropics of both hemispheres, where there are many other species of more restricted range, and so presumably younger.

Eu-Pteris, with free veins, contains several groups, perhaps independently related to *Litobrochia*. *P. cretica* L. is in New Zealand and South Africa, ranging northward to Japan, the Mediterranean, and into the United States. *P. vittata* has the same old-world range. *P. tremula* R. Br. is in New Zealand, Tasmania, and doubtfully in South Africa. Each of these three represents a natural group of species. *P. chilensis* is in Chile and Juan Fernandez; there are 2 other Chilean species.

P. paleacea is endemic in Santa Helena. A genus with about 260 species in the Tropics, and 5 confined to the far South, might be presumed to be tropical in origin. When, however, we consider the probability that the forbears of *Pteris* were Antarctic, and the fact that most wide-ranging, and therefore probably oldest and most primitive species of the several groups still exist in the South, we recognize the southern survivors as laggards along the path of migration, and conclude, too, that the differentiation of the groups preceded the northward migration. The present multitude of tropical species merely demonstrates the use of the recent and present opportunity for evolution under perfect and diversified climatic conditions, with ample room.

Adiantum, with 226 species, is the other large genus of this alliance. It is more isolated (without near relatives), and therefore presumably older. It has a disproportionate number of southern species, 12 in Madagascar, 7 in New Zealand. *A. scabrum* Kaulf. and *A. sulphureum* Kaulf. represent it in southern Chile, and *A. tenerum* Sw. in Juan Fernandez. *A. aethiopicum* L. is in South Africa and New Zealand, but does not range far north. *A. hispidulum* Sw. is in the same southern lands, but is distributed as continuously as land and climate permit from both of them to India. There are also a few distinctly northern species, notably *A. pedatum* L. The reasonable conclusion is that Antarctica has played a major part in the history of today's *Adiantum*, but that the genus may include elements surviving from other floras and from an age prior to the great dispersal from the South.

The fondness of gardeners for *Adiantum* is based jointly on its beauty and on the ease of reproducing it by spores. Some thirty years ago, Dr. W. R. Shaw, in work never published, undertook to grow in the laboratory a large number of Philippine ferns. The spores of every common fern, and of almost no rare fern, germinated for him. This should go far to explain why some ferns are common and others rare, a phenomenon too completely ascribed to other factors,—climate, exposure, soil, age. Every tested *Adiantum* germinated, and its spores are evidently exceptional in vigor and viability. The spores of *A. philippense* L., common about Manila, were probably brought inadvertently to Acapulco by the galleons. It is now well established in southern Mexico, and has reached Central America. This matter of the viability and vigor of the spores, as far as

we are informed about it, should be taken into account in any study of the significance of distribution. The time which permits an *Adiantum* to acquire a wide range might leave a *Cyathea*, difficult to cultivate by spores, still almost local.

Going back to *Dennstaedtia*, another revolutionary line leads to *Lindsaya*, a genus of 159 species, with the same distribution picture as *Dennstaedtia*. It has 5 New Zealand species, and 7 in Madagascar. Its related genera are similarly distributed. Several other groups of genera are traceable back to the *Dicksonia* group, and present essentially the same present map as the coördinate groups already discussed. The itemization of the evidence, and repeated drawing of the same conclusions, become too monotonous; and the validity of the argument ceases to gain strength by repetition, once it is well established.

There is, however, one group of very many genera which presents distinct problems, that of *Cheilanthes* and its relatives, to which the genera often treated as a tribe typified by *Gymnogramme* are related by so many ties that all, together, must constitute one natural alliance. Christ aptly characterized these as the xerophilous ferns, the ferns of dry lands. There is evidence enough for the southern origin of the group as a whole. But this evidence would become perfect, as in the case of the Hymenophyllaceæ, only if the several genera were shown to be Antarctic in origin, thus fixing Antarctica as the place of their evolution. I cannot do this for the group in question, because there is no sound agreement as to what the genera are. The large cheilanthoid genera of the Index are not such in any proper sense. *Cheilanthes* and *Pellaea* are unnatural aggregates of genera, as is probably true of *Gymnogramme*, and certainly of *Notholaena*.

Such a study as this may be most helpful in determining the real genera. For, the morphologist can never draw a conclusion as to the relationships of a plant without at the same time postulating its history. His ultimate subject is phylogeny; and where this field is still dark, a little light from the side of history may make its exploration easy. The presumption that the differentiation of the genera occurred in the far South, and that they migrated northward along a few known paths, may provide this light. A decade ago [17] I outlined the phylogeny of the typically oriental genera, but abstained from speculation

[17] The Oriental Genera of Polypodiaceæ. Univ. Calif. Publ. Bot. (1928).

as to the relatives of *Cheilanthes*, believing that their evolution had taken place in America. Subsequent study of American ferns has cleared up only minor details. Now I conclude that this differentiation of the principal genera did not take place in America, either. Unfortunately we have not the ferns of oligocene Antarctica, but a study of the survivors along the paths of migration is still inviting.

To summarize as to the dicksoniid ferns: Their general evolution occurred in Antarctica. The principal genera were differentiated there, and their present representatives are migrants thence, or the descendants of migrants. This accounts for roughly one-fifth of all Polypodiaceæ.

In *Cyathea* must be included very nearly, but not quite, all of the species of *Alsophila* and *Hemitelia* rather than be left in those genera, making *Cyathea* a genus of about 750 species. *Lophosoria*, one variable species, and *Metaxya*, one species, are clearly distinct and primitive. The tree ferns as a whole await the study which may show how they can be broken up into natural genera of convenient size. This leaves us where we were with the Hymenophyllaceæ divided into 2 genera only and their Antarctic origin not suspected. There is no such proportion of far-southern to tropical species in *Cyathea* as there was in *Hymenophyllum*, because the current evolution of the tree ferns is exceedingly active, a very large part of the recognized species being strictly local. Still, the southern character of the group is clear, in broad lines if not in detail. A few species pass the Tropic of Cancer in Formosa, and one reaches Japan proper. As far as numbers go, just within the Tropics, Madagascar's 29 species are offset in Luzon, but there are two significant differences: Luzon is open to free colonization from the South, while Madagascar is comparatively cut off from the North; and one of the groups susceptible of generic status is confined to Madagascar. More significant in the latter way is the abundance in southern Chile and Juan Fernandez of *Lophosoria* (which ranges northward to Mexico), a primitive member of the group. New Zealand has seven species, and at least four more are extratropical in the same region.

No ferns are suspected of descent from *Cyathea*. Nevertheless, about one-third of the species usually included in Polypodiaceæ seem to have a common ancestor with it, to be much nearer to it than any other comparatively primitive ferns, and therefore likely to have the same origin in ancient geography.

Four important genera are nearly related in their more primitive representatives: *Dryopteris, Polystichum, Athyrium,* and *Cystopteris. Cystopteris fragilis* (L.) Benth. is conspicuously common in the far South and about equally so in the far North. It is too perfectly cosmopolitan for its distribution to present evidence for anything except that it spreads with facility and is not very new.

Dryopteris, 1,213 species in the Index, is an assemblage of genera that must be segregated in their entirety before they are ready for use in a study based on distribution. This genus also is found in the Upper Cretaceous of Patagonia. I have little doubt that the group as a whole is of southern origin; but, as in the case of *Cheilanthes,* will suggest this as a point of view in the study of the group, rather than attempt a detailed argument while I am not sure of the genera to which the southern species should be assigned.

Polystichum, 225 species, is a smaller collection of potential genera, in part so near to a part of *Dryopteris* that species are constantly shifted back and forth, not as a matter of definition, but because their nearer affinity is in doubt. The species are most numerous in and near China, evidently the center of greatest recent evolutionary activity. This recent activity, though, is in the least primitive section of the genus, that with simply pinnate fronds, represented in the South only in South Africa. The most compound element in the genus, nearer to *Dryopteris,* is represented by *P. adiantiforme* (Forster) J. Sm., in New Zealand, the Cape, Chile, and Juan Fernandez. *P. aristatum* (Forster) Presl. is in Natal, New Zealand, Rapa, and Pitcairn in the remote South Pacific, and ranges northward to Japan. The cosmopolitan group of *P. aculeatum,*—that species itself in South Africa,—is the best represented in the far South. *P. mohrioides* (Bory) Presl is a typical survivor of the Antarctic flora, in Antarctic America and all neighboring islands, Tristan da Cunha in the middle South Atlantic, and Amsterdam and Saint Paul islands in the southern Indian Ocean, with a northward range only to Peru. *P. vestitum* (Forster) Presl is in Tasmania, New Zealand, and Antarctic America. In all, Chile has 9 species, besides one in Juan Fernandez; New Zealand, 7; South Africa, 6; and the tiny island of Rapa, well out of the Tropics and two thousand miles east of New Zealand, has 3. The case for an Antarctic origin of *Polystichum* is so clear that the evidence has long been familiar, even to those hes-

itant to draw the obvious conclusion. The origin of *Polystichum* being established, the necessity of a common geographic origin for *Polystichum* and *Dryopteris* helps to fix that of the latter genus.

A considerable number of genera are dryopterid in ancestry and must therefore have a common old geographic center. Some of these indicate it by their distribution. But the argument is not impaired by others which do not, being evidently younger, evolved since the dispersal, in the regions to which they are still confined. The listing of the genera, with the respective arguments, would be superfluous.

Athyrium, if *Diplazium* be included, is a genus of 568 species. It is so in need of revision, and of the recognition or discovery of the component natural groups, that I content myself here with indicating its probable or assumed affinity to *Dryopteris* and *Blechnum*, and the consequent necessity of a common geographic origin.

Blechnum, 180 species, is one of the most obviously austral genera. It is the only large genus which, in spite of the disparity of the land areas, still has many more species (131 to 78) south of the equator than north of it. Significant species are *B. attenuatum* (Sw.) Mett., in South Africa and New South Wales; *B. tabulare* (Thunb.) Kuhn, in South Africa and South America, even to Desolation Island; *B. australe* L., in South Africa and several far-southern islands; *B. lanceolatum* (R. Br.) Sturm, in Chile, New Zealand, and Tasmania; and *B. Penna-marina* (Thunb.) Kuhn, with circumpolar distribution missing few possible spots. In all, South Africa has 8 species, Antarctic America 15 besides 3 endemics in Juan Fernandez, and New Zealand 15. Farther along a main route of migration, New Caledonia is remarkably rich in this genus.

Remarkable in a group so predominantly southern is the northern circumpolar range of *Blechnum spicant* L. *Blechnum* is not a young genus, and may be a remnant of a flora as old as the Cretaceous,—that is, "pre-Antarctic." Or, even this species may possibly be of southern origin, along with its congeners. The time between the great migration from Antarctica, Miocene at the most recent, and the refrigeration of the North which made the present distribution of *B. spicant* somewhat discontinuous, could easily have permitted a fern particularly able to migrate to reach the neighborhood of the other pole and spread over that region, while the climate there

was the same it had evolved in adaptation to in the South. *B. spicant* and *B. Penna-marina* are near relatives.

The huge genus *Asplenium*, 664 species after the removal of *Loxoscaphe*, is a collection of groups of species, very badly in need of revision. Some of these groups are manifestly of southern origin; others not so evidently so, but presenting no evidence on the other side. It has always been assumed to be nearly related to *Athyrium*. If this be so, it is a younger genus; and unless both date from some such period as the Cretaceous, it must be wholly of southern origin if *Athyrium* is so. I think it probable that *Asplenium* is wholly southern, but would not like to rest the case on its affinity to *Athyrium*.

What is true of *Asplenium* must be true, even if indirectly, of the genera derived from it. As to some of them, *Stenochlaena* and its apparent relatives, and *Diplora*, this looks probable from their own distribution. Others, such as *Phyllitis*, are newer, evolved since the dispersal, even if old enough to have their present range influenced by the northern glaciation.

To sum up on the *Cyathea-Dryopteris-Athyrium* series of genera: some of them are positively Antarctic in origin; others are probably so. Chiefly because the really natural genera combined at present in *Dryopteris*, *Asplenium*, and others are too insufficiently understood to serve the purpose, the evidence is hardly as complete and perfect as it is for the dicksoniid series; but it is good enough to make highly probable the southern origin of the group as a whole. More than one-third of all fern species are in this series.

Polypodium and its relatives constitute the third great group of genera in this family. They are believed to be descended from ancient ferns now most nearly represented by *Dipteris*, or, still more primitive, by *Matonia*, and may be called the *Matonia-Dipteris-Polypodium* series. Fossils of ferns believed to be near the living *Matonia* and *Dipteris* are known in the North, and it is not known that either of these was ever in the South. *Polypodium* itself, typified by *P. vulgare* L., and including many species which have been called *Goniophlebium*, must, by the criteria we have been using, be regarded as a northern genus. However, there is no presumption that the taxonomic type represents the genus in any other respect; and the great genus *Polypodium* of the Index, with 1,127 species, includes elements which seem to be immigrant to the Tropics from the South.

Grammitis, a remarkably uniform genus of about 125 species, is one of these. The species known only from south of the equator, about 65, outnumber those known only from north of it, about 35, and ranging across it, about 25, together. It has one circumpolar species, *G. Billardieri* Willd., in New Zealand, South Africa, Antarctic America, and several Antarctic islands. The genus migrated northward by the three great routes, some 15 species being American, about 90 Oriental, and nearly 20 African (including islands); and no species except *G. Billiardieri* is common to two of these. The case for its Antarctic origin is plain enough.

Loxogramme, 36 species, is very nearly related to *Grammitis*. It inhabits less humid woods, and therefore its spores pass more readily into free air; therefore, its species are in general less local,—the difference in this respect is very marked. Migrating easily, *Loxogramme* has passed *Grammitis*, and becomes a genus of the northern Tropics, with a number of species beyond the Tropic of Cancer, even in Japan. A single species, *L. Dictyopteris* (Mett.) Copel., survives in New Zealand. Four species are African, perhaps immigrants via the Cape, perhaps from Malaya. A single American species is Mexican, and I regard it as of recent Japanese origin.

The case of *Loxogramme* illustrates the control of judgment by the point of view. If the assumption were that ferns are a northern group, *Loxogramme*, with 16 species known only north of the equator and 6 only south of it; with 5 species known in and north of Formosa, and 1 in New Zealand, and with this one interpreted then as migrant from the Tropics with most other New Zealand ferns;—*Loxogramme* would conform perfectly to the assumption. On the other hand, recognizing *Loxogramme* as a near relative of *Grammitis*, and *Grammitis* as a southern genus; interpreting the difference in distribution to the north as a natural result of a difference in facility of migration, which I know on other grounds to exist; knowing that the Japanese region has been populated on a great scale by ferns from the South; believing that no fern has reached New Zealand from the Tropics in a million years, and that this can be so only because migration to New Zealand from the North is effectively impossible, I fit *Loxogramme* into my picture of a fern world of far-southern origin.

Several smaller genera of this series are clearly Antarctic in origin; such are *Synammia* and *Dictymia*. Others are of more recent evolution, with Antarctic forbears; this is the ap-

parent case with *Scleroglossum* and *Calymmodon.* Of larger genera, *Cyclophorus* with 100 species, and *Ctenopteris* with 200, are more than probably austral in ancestry. The largest genus of this series, after *Polypodium* is broken up, is *Elaphoglossum.* Several items of evidence indicate that it too has come to the Tropics from the far South. A natural grouping of its more than 350 species is necessary before this becomes a conclusion instead of a probability.

To sum up as to the *Matonia-Dipteris-Polypodium* series: There is good evidence for the Antarctic origin of about half of the species. As to the others, or most of them, the evidence of present distribution is compatible with this idea, but has less affirmative value. And even as to *Polypodium,* distinctively northern now, I have already pointed out that time, which has not yet permitted ferns of little expansive power, like the Hymenophyllaceæ, *Cyathea, Dicksonia,* and *Grammitis* to reach northern lands, was quite sufficient to permit more capable migrants to become established there long ago. However, *Polypodium* is probably no such capable migrant as *Adiantum, Dryopteris,* and *Athyrium.*

Family 8. Marsileaceæ.—The family Marsileaceæ includes 3 genera; *Marsilea* with 67 species, and *Pilularia* with 6, both of world-wide distribution, and the third known only in southern Brazil. These are aquatic ferns, with sporocarps too large to be wind-borne, and spores of the briefest vitality once they are exposed. Migration to any distance is probably dependent upon birds. The southern origin of *Marsilea* is indicated by the fact that more than half of all known species are African, 24, and Australian, 16. Of the 6 species of *Pilularia,* one ranges from Chile to California; one is endemic in New Zealand; one in Tasmania and Australia. Comment is unnecessary. Bower relates this family to the Schizæaceæ, and the evidence of distribution points clearly to the same old common home.

Family 9. Salviniaceæ.—The family Salviniaceæ includes 2 genera: *Azolla,* 6 species; *Salvinia,* 10. These are floating aquatics, with smaller sporocarps, more readily carried by birds: the species, accordingly, are of wider range than those of the Marsileaceæ. *Azolla filiculoides* Lam. is in Chile, Argentina, Brazil, and California. *A. pinnata* R. Br. is in Australia, ranging to Japan and Africa. *A. rubra* R. Br. is confined to New Zealand and Australia. These being half of the species in the genus, it may be concluded that the genus was

Antarctic, and emigrated by at least two routes. As to *Salvinia*, the species are largely tropical, but so scattered that no conclusion may be drawn from present distribution and ranges.

This ends the canvass of the families, and brings us to the conclusion that more than half of the living fern species are descendants of migrants from Antarctica. The geologist tells us that such migration from Antarctica itself ceased by the Miocene; it might have occurred indefinitely earlier, but there is nothing in present distribution which demands an earlier date. While the migration from Antarctica ceased at such a time, the plants then established outside Antarctica continued to multiply, to evolve new species and new genera, and to spread, northward, and fanwise, as wind carried the spores and there was fit land to receive them. And these processes of migration and evolution still go on. The evidence adduced applies to more than half of the living ferns. No comparable evidence indicates any other particular origin for one-tenth of the species. To the more-than-half, of fairly demonstrable southern ancestry, analogy and apparent affinity will justify the addition of at least another quarter.

Antarctica has played, in its time, a dominant part in the evolution of our fern world. This is our thesis. But there are corollaries, and incidental conclusions, and new questions inviting further study. The thesis is a new light on pteridology, in a measure a new light on the history of plants, and a new light brings out things that were dark. The number of New Caledonian ferns has long been regarded as remarkable. But when it is realized that New Caledonia is the first island of any size with a moist, warm climate along a main line of migration into the Tropics, and thus has an old flora as tropical fern floras go, it is plainly only natural that it has become rich in species. Madagascar, similarly placed on another path, is likewise and for the same reason rich in ferns.

New Guinea has the world's richest fern flora; Christensen [18] believes that it will prove to have 2,000 species. Borneo has been famous for its wealth of ferns, but no estimate has placed its number above 1,000. If Malaya were the center of evolution and distribution it has been supposed to be, Borneo should be the richest fern land in the world. But when we realize that

[18] Brittonia 2.

New Guinea was the first land with ideal and diversified climate and large enough to favor the free evolution of species, along the open path of migration from New Zealand and Tasmania, and that therefore it has the oldest great fern flora in the Orient, its wealth of species is only what would be expected. The old concept of a Malayan flora spreading across New Guinea to Polynesia, which I have accepted and presented as one of the data of fern geography, was essentially wrong. Between Papua and Malaya, fern migration has been from the richer to the poorer flora, with the wind, chiefly westward.

What about migration within Polynesia? Has it been, as assumed, eastward,—say from the New Hebrides and the Solomons to Fiji, Samoa, Tahiti, and even to Pitcairn and Henderson? Or did Rapa once receive ferns from the South, and pass them along to the North and West?

We have always been rather surprised by the affinity of Mindanao and New Guinea ferns, but will be so no longer. As climates are today, Celebes being in general drier than New Guinea, Mindanao, and Borneo, Mindanao was the most ready recipient of spores from New Guinea. We have always seen a dominant Malayan element in the Philippine flora. How real is it? Did ferns really come from Borneo to Mindanao, as much as they went from Mindanao to Borneo?

A great fern center, of radiation as well as of endemism, has been postulated in the Yunnan-Assam region. Is it as important as it has seemed to be? Is it still a sound presumption that a fern found here and in Formosa and Luzon originated on the continent? This should be tested case by case before the presumption is maintained. It may be correct as to *Plagiogyria,* and not as to *Cheilanthes.* The foregoing are but samples of the questions that arise or are revived.

The conditions of fern dissemination have been assumed more than investigated. They have to be considered in such a study as this, and surely ought to be studied themselves. Limited vitality of the spores has been assumed to limit the possible distance of flight over the sea, even to the point of postulating old land connections to explain the presence of Hymenophyllaceæ on remote islands. I rate this as in general a minor factor. But I do not understand the northern occurrence of one and only one *Schizaea; Schizaea* inhabits exposed places, whence the spores should be taken up readily by the wind.

The light which the southern origin throws on questions of taxonomy has already been suggested, but it opens too large a field for elaboration here.

What is true of as great and diversified a family as the Filices may be expected to be equally true of some other large families. The Proteaceæ are a recognized case. It might well pay to examine the Rosaceæ, Rubiaceæ, and Orchidaceæ as to distribution and history.

Finally, it is fit that I disclaim anything more than I have said. Ferns existed well over the world longer ago than I would try to explain their presence as emigrants from Antarctica, and must be supposed to have maintained continuous existence elsewhere. This being so, the preponderance of ferns of apparent Antarctic origin in the world today is surprising indeed.

ILLUSTRATIONS

TEXT FIGURES

FIG. 1. The Pacific Ocean.
2. The region around the South Pole.

MARINE DIATOMS FOUND IN WASHINGS OF SEA WEEDS FROM FUKIEN COAST

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The 6 samples listed below were collected from Fukien Coast. Samples 1 to 5 were collected in Amoy and its vicinity, while sample 6 was collected from Haitan. Altogether 68 species were found in washings of different species of sea weeds; 15 species were newly recorded for China Coast; 3 brackish-water and 2 fresh-water species were found, since the inland fresh water easily reached the collecting ground. The new and rare species found will be described later.

Melosira moniliformis, Coscinodiscus lineatus, Coscinodiscus excentricus, C. radiatus, Arachnoidiscus ornatus, Grammatophora marina, and *Achnanthes brevipes* were the most common and most abundant diatoms obtained from sea weeds.

Sample 1.—Collected from Nantaiwu, south of Amoy, April 23, 1936. Ten species were found.

Sample 2.—Collected from Nantaiwu, south of Amoy, July 18, 1936. Thirteen species were found.

Sample 3.—Collected from Tseng Shu An, eastern coast of Amoy Island, June 5, 1936. Twenty-one species were found.

Sample 4.—Collected from Kulangsu, southwest of Amoy, October, 1937. Thirty-two species were found.

Sample 5.—Collected from Song Su, west of Amoy, June, 1937. Twenty-five species were found.

Sample 6.—Collected from Ox Mountain Light House, Haitan, May 12, 1937. Thirty-four species were found.

DIATOMS FOUND

MELOSIRA JUERGENSI Agardh.

Found in samples 5 and 6.

MELOSIRA GRANULATA (Ehr.) Ralfs.

Found in sample 5.

MELOSIRA MONILIFORMIS (Müll.) Agardh.

Found in samples 1, 3, 4, 5, and 6.

PARALIA SCULATA (Ehr.) Cleve.

Found in samples 1, 5, and 6.

PODOSIRA HORMOIDES (Mont.) Kützing.

Podosira hormoides (Mont.) Kützing, HUSTEDT (1928) 283, fig. 123.

Found in sample 4.

ACTINOCYCLUS EHRENBERGI Ralfs.

Found in samples 2 and 3.

ACTINOCYCLUS EHRENBERGI var. CRASSA (W. Sm.) Hustedt.

Actinocyclus Ehrenbergi var. *crassa* (W. Sm.) HUSTEDT (1929) 529, fig. 301.

Found in sample 3.

COSCINODISCUS SUBTILIS Ehrenberg.

Found in samples 2, 3, 4, and 5.

COSCINODISCUS LINEATUS Ehrenberg.

Found in samples 1, 2, 3, 4, and 6.

COSCINODISCUS EXCENTRICUS Ehrenberg.

Found in samples 2, 3, 4, 5, and 6.

COSCINODISCUS NODULIFER Schmidt.

Coscinodiscus nodulifer Schmidt, ALLEN & CUPP (1935) 116, fig. 9.

Found in sample 2.

COSCINODISCUS RADIATUS Ehrenberg.

Found in samples 1, 2, 3, 4, and 6.

COSCINODISCUS ASTEROMPHALUS Ehrenberg.

Found in sample 3.

COSCINODISCUS CURVATULUS Grunow.

Found in samples 4 and 5.

COSCINODISCUS MARGINATUS Ehrenberg.

Found in sample 4.

COSCINODISCUS JANISCHII Schmidt.

Found in samples 4 and 5.

COSCINODISCUS JONESIANUS var. COMMUTATA Hustedt.

Coscinodiscus Jonesianus var. *commutata* Hustedt, ALLEN & CUPP (1935) 117, fig. 11.

Found in sample 6. First record for China Coast.

COSCINODISCUS NOBILIS Grunow.

Found in sample 6.

CYCLOTELLA STRIATA (Kütz.) Grunow.

Found in samples 2 and 5.

CYCLOTELLA COMTA (Ehr.) Kützing.

Found in samples 3 and 4.

CYCLOTELLA STYLORUM Brightwell.

Found in sample 4.

ARACHNOIDISCUS ORNATUS Ehrenberg.

Arachnoidiscus ornatus Ehrenberg, V. HEURCK (1896) 506, fig. 255.

Found in samples 1, 3, 5, and 6.

ACTINOPTYCHUS UNDULATUS (Bail.) Ralfs.

Found in samples 3 and 4.

ASTEROMPHALUS FLABELLATUS Greville.

Found in sample 6.

TRICERATIUM ANTEDELUVIANUM (Ehr.) Grunow.

Tricheratium antedeluvianum (Ehr.) Grunow, HUSTEDT (1930) 810, fig. 472.

Found in sample 6. First record for China Coast.

TRICERATIUM FORMOSUM Brightwell.

Triceratium formosum Brightwell, HUSTEDT (1930) 891, fig. 481.

Found in sample 6.

BIDDULPHIA PULCHELLA Gray.

Found in samples 2, 3, 4, and 6.

BIDDULPHIA OBTUSA Kützing.

Found in samples 1 and 5.

BIDDULPHIA RETICULUM (Ehr.) Boyer.

Biddulphia reticulum (Ehr.) Boyer, ALLEN & CUPP (1935) 147, fig. 83.

Found in sample 6. First record for China Coast.

BIDDULPHIA AURITA (Lyn.) Brebisson.

Found in sample 6.

BIDDULPHIA AURITA var. OBTUSA (Kütz.) Hustedt.

Found in samples 1 and 5.

BIDDULPHIA LAEVIS fo. MINOR V. Heurck.

Found in sample 4.

FRAGILLARIA CROTONENSIS (A. M. Edwards) Kitton.

Found in sample 6.

RHABDONEMA ARCUATUM (Ag.) Kützing.

Rhabdonema arcuatum (Ag.) Kützing, V. HEURCK (1896) 360, pl. 12, fig. 487*a*.

Found in sample 6. First record for China Coast.

RHABDONEMA ADRIATICUM Kützing.

Found in samples 3, 5, and 6.

GRAMMATOPHORA MARINA (Lyn.) Kützing.

Found in samples 3, 4, 5, and 6.

GRAMMATOPHORA MARINA var. MACILENTA V. Heurck.

Grammatophora marina var. *macilenta* V. HEURCK (1896) 354, pl. fig. 480*a*.

Found in sample 4. First record for China Coast.

LICMOPHORA ABBREVIATA Agardh.

Found in samples 5 and 6.

CLIMASCOPHENIA MONILIGERA Ehrenberg.

Found in sample 2.

SYNEDRA GALLIONII Ehrenberg.

Found in samples 3, 4, 5, and 6.

ACHNANTHES BREVIPES Agardh.

Found in samples 2, 4, 5, and 6.

COCCONEIS DISRUPTA Greg.

Cocconeis disrupta Greg., V. HEURCK (1896) 290, pl. 8, fig. 343.

Found in samples 4, 5, and 6. First record for China Coast.

COCCONEIS MOLESTA Kützing.

Cocconeis molesta Ktz., V. HEURCK (1896) 290, pl. 29, fig. 823.

Found in sample 4. First record for China Coast.

COCCONEIS SCUTELLUM Ehrenberg.

Found in samples 1, 3, and 6.

NAVICULA CANCELLATA Donkin.

Found in sample 6.

NAVICULA IRIDIS (Ehr.) Cleve.

Navicula iridis (Ehr.) Cleve, DONKIN (1870) 31, pl. 5, fig. 7.

Found in sample 6. First record for China Coast.

NAVICULA FORTIS Greg.

Navicula fortis Greg., DONKIN (1870) 57, pl. 8, fig. 8.

Found in sample 6. First record for China Coast.

NAVICULA CRABRO Ehrenberg.

Found in sample 6.

NAVICULA ABRUPTA Greg.

Navicula abrupta Greg., DONKIN (1870) 13, pl. 2, fig. 6.

Found in sample 2. First record for China Coast.

TRACHYNEIS ASPERA Ehrenberg.

Found in samples 1, 3, 4, 5, and 6.

CYMBELLA ASPERA (Ehr.) Cleve.

Cymbella aspera (Ehr.) Cleve, V. HEURCK (1896) 146, pl. 1, fig. 35.

Found in sample 4. Fresh-water species.

AMPHORA SALINA W. Sm.

Amphora salina W. Sm., V. HEURCK (1896) 134, pl. 1, fig. 6.

Found in sample 6. First record for China Coast. Brackish-water species.

AMPHORA COSTATA W. Sm.

Amphora costata W. Sm., V. HEURCK (1896) 133, pl. 24, fig. 67.

Found in sample 2.

PLEUROSIGMA NAVICULACEUM Brebisson.

Pleurosigma naviculaceum Brebbisson, ALLEN & CUPP (1935) 157, fig. 103.

Found in sample 4. First record for China Coast.

PLEUROSIGMA RIGIDUM W. Sm.

Pleurosigma rigidum W. Sm., V. HEURCK (1896) 251, pl. 6, fig. 265.

Found in sample 4. First record for China Coast.

PLEUROSIGMA NORMANII Ralfs.

Found in samples 3, 4, and 6.

PLEUROSIGMA ANGULATUM Ehrenberg.

Found in samples 3, 4, and 5.

GYROSIGMA BALTICUM W. Sm.

Found in samples 3 and 4.

SURIRELLA FASTUOSA Ehrenberg.

Surirella fastuosa Ehrenberg, V. HEURCK (1896) 372, pl. 13, fig. 583.

Found in samples 4, 5, and 6.

SURIRELLA FLUMINENSIS Grunow.

Found in sample 4.

CAMPYLODISCUS HODGSONII W. Sm.

Campylodiscus Hodgonii W. Sm., V. HEURCK (1896) 376, pl. 32, fig. 868.

Found in samples 4 and 5. First record for China Coast.

CAMPYLODISCUS (?) COCCONEIFORMIS Grunow.

Found in sample 2.

BACILLARIA PARADOXA Gmelin.

Found in sample 6.

NITZSCHIA SUBTILIS Grunow.

Nitzschia subtilis Grunow, V. HEURCK (1896) 401, pl. 17, fig. 552.

Found in sample 5. First record for China Coast. Freshwater species.

NITZSCHIA PUNCTATA (W. Sm.) Grunow.

Found in sample 4.

NITZSCHIA SIGMA var. INTERCEDENS Grunow.

Nitzschia sigma var. *intercedens* Grunow, V. HEURCK (1896) 396, pl. 16, fig. 531.

Found in sample 3. Brackish-water species.

NITZSCHIA LORENZIANA (W. Sm.) Grunow.

Found in samples 1, 4, 5, and 6. Brackish-water species.

HANTZSCHIA MARINA (Donkin) Grunow.

Hantzschia marina (Donkin) Grunow, V. HEURCK (1896) 382, pl. 15, fig. 489.

Found in sample 2. First record for China Coast.

TRIVERBAL SPECIFIC NAMES

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At the last Botanical Congress, Amsterdam (1935), Dr. A. Becherer proposed as follows:

> The names *Asplenium Trichomanes dentatum* L. Sp. Pl. (1753) 1080 and *A. Trichomanes ramosum* L. op. cit. 1082, must be rejected since they are liable to be confused with the name *A. Trichomanes* L. Sp. Pl. 1080. The valid names are *A. dentatum* L. (1759) and *A. viride* Huds. (1762).

Whereupon Dr. T. A. Sprague observed that:

> The names *A. Trichomanes dentatum* and *A. Trichomanes ramosum* are intrinsically invalid, since they were not published as *binary* combinations (see Art. 27).—Sprague, Synopsis of Proposals (1935) p. 74.

I would suggest that Article 27 does not apply in this case, for surprising as it may be, the wording of Article 27, far from condemning triverbal specific names, actually provides a means whereby certain triverbal specific names may be transformed into valid biverbal ones. In fact, despite the spirit of the rules, there is no express condemnation of triverbal specific names having biverbal specific epithets as such, except when individually the specific names do not refer to two valid descriptions, one generic and the other specific, or when they are found in works "in which the Linnean system of binary nomenclature for species was not consistently employed." (Article 68, 4). But in this last case not only triverbal specific names but also biverbal names must be rejected.

In order to enable the reader the better to follow my contention I transcribe here Article 27:

> Names of species are binary combinations consisting of the name of the genus followed by a single epithet. If an epithet consists of two or more words, these must either be united or joined by hyphens. Symbols forming part of the specific epithets proposed by Linnæus must be transcribed . . . . . .

Proof that my interpretation of the wording of Article 27 is correct is found in the examples given under the same Article. For instance, in the case of symbols, Linnæus did

not use a hyphen between the symbol and the word preceding it, but in the examples the symbols are not only transcribed but the hyphens are added. Furthermore, the specific epithet in *Adiantum Capillus veneris* L. (1753), *Impatiens Noli tangere* L. (1753), or *Atropa Bella dona* L. (1753) consists of two separate words, but in the samples the epithets have been united or hyphened to make the names biverbals. Had Doctor Sprague's contention been right, *A. Capillus veneris, Impatiens Noli tangere,* and *Atropa Bella dona* ought to have been rejected as "intrinsically invalid" names. Also in "Species Lectotypicae Linnaei," printed in the 1935 rules, the Linnæan triverbals, *Bignonia unguis cati, Choix lachryma jobi, Strychnos nux vomica, Trigonella foenum graecum, Ipomoea pes tigridis,* and others, have been consistently transformed into biverbals either by hyphening or by uniting the two separate words in each of the specific epithets.

Now *Asplenium Trichomanes dentatum, A. Trichomanes ramosum, Adiantum Capillus veneris, Impatiens Noli Tangere,* and *Atropa Bella dona* were all published as specific names not only under identical conditions but also in the same book; namely, Species Plantarum, 1753; and so there is no reason why, for purposes of validity, the first two triverbal names should be treated differently from the last three. Consequently, *Asplenium Trichomanes dentatum* and *A. Trichomanes ramosum,* like the other three names, should be accepted as valid binary names and transformed into biverbals in accordance with the provisions in Article 27.

Whether or not it is advisable to allow a valid status to non-Linnæan triverbal specific names is a matter that should be considered by the future Congress; but in arriving at such a decision consideration must be given to the question whether it is desirable to reject as invalid names like *Xanthophytum Johannis Winkleri* Merr.[1] and *Tibouchina Campos Portoi* Brade.[2] If, on the other hand, the omission of the hyphen is taken as a typographic or orthographic error, such biverbal generic names as *Chamae Filix* Hill, *Filix Foemina* Hill, *Adiantum album* Hill, *Capillus veneris* Hill, or multiverbal or phrase names of species, might be taken as valid, creating thereby a

[1] Mitt. Inst. Hamburg. Bot. 7 (1937) 271.
[2] Arch. Inst. Biol. Veget. Rio de Janeiro 4 (1938) 78.

necessity either for effecting many nomenclatural changes or for making special decisions to prevent those changes.[3]

In my opinion difficulties such as the above may be satisfactorily obviated both by adopting the distinctions between binary, binomial, and biverbal names given by me in this Journal [4] and by invalidating all binary binomials which are not biverbal, validity being allowed to biverbal specific epithets that occur as exceptions in papers that have in general fulfilled the rule.

[3] See also Farwell, Amer. Midl. Nat. 12 (1931) 233.
[4] Philip. Journ. Sci. 69 (1939) 467.

DETERMINATION OF THE PISCINE INTERMEDIATE HOSTS OF PHILIPPINE HETEROPHYID TREMATODES BY FEEDING EXPERIMENTS

PROGRESS REPORT [1]

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FOUR PLATES

In a previous paper(18) we published the results obtained in feeding experiments with 6 species of fish, namely, *Hepsetia balabacensis, Hemiramphus georgi, Ambassis buruensis, Mugil* sp., *Arius manillensis,* and *Clarias batrachus.*[2] Since then 11 more species of fish have been experimented with in the same way, and feeding experiments with *Arius manillensis, Ambassis buruensis,* and *Hemiramphus georgi* have been repeated. The results obtained constitute the subject of this report. The additional species of fish used this time were *Ophicephalus striatus,* locally known as *dalag; Glossogobius giurus, biá; Therapon plumbeus, ayuñgin; Gerris kapas, malakapas; Gerris filamentosus, malakapas; Creisson validus, biá ng sapa; Anabas testudineus, martinico; Ophiocara aporos, bangayngay; Pelates quadrilineatus, babansi; Teuthis javus, samaral;* and *Eleutheronema tetradactyla, mamale.*

Of the above fish, *Ophicephalus striatus, Therapon plumbeus, Anabas testudineus,* and *Opiocara aporos* are fresh-water fishes and the others are marine fishes, according to Dr. Deogracias Villadolid, ichthyologist of the Bureau of Science, Manila, who kindly identified them for us.

MATERIALS AND METHODS

The practice and technic described in the previous report were faithfully followed in the experiments reported in this paper.

[1] Aided by a special research grant from the Board of Regents, University of the Philippines.

[2] In the previous report this strictly fresh-water fish was accidentally listed as marine.

RESULTS

In Tables 1 to 14 we have recorded the results of our feeding experiments separately for each species of fish used by us.

REMARKS

Ten more piscine intermediate hosts (Tables 1, 2, 3, 4, 5, 6, 7, 9, 10, 11, and 13) of Philippine heterophyid trematodes have been determined, and 4 species of heterophyids have been added to our previous list of 9 experimental heterophyids; namely, *Haplorchis pumilio* (= *Monorchotrema taihokui*), *Haplorchis taichui* (= *Monorchotrema taichui*), *Haplorchis sisoni* sp. nov., and *Stamnosoma formosanum*. Incidentally, one echinostomatid and one strigeid, represented by *Echinochasmus novalichesensis*(17) and an unidentified *Neodiplostomum* species, have also been recovered experimentally from 3 and 4 different piscine species, respectively (Tables 1, 2, 3, 8, and 12). Although *Echinochasmus* and *Neodiplostomum* are not heterophyids, we include them in this report for the sake of completeness. *Haplorchis sisoni*, a new species discovered in this series of experiments (Table 3), has been described by one of us (C.M.A.) in a separate paper. Our *Stamnosoma* specimens, recovered from four different piscine hosts (Tables 1, 2, 3, and 7), are all of one species, *ovigerous*, with two rows of circumoral spines (17 to each row), smoothly contoured testes, long intestine, and conspicuous ventral sucker, and are morphologically indistinguishable from mounted specimens of *Stamnosoma formosanum* obtained from Taihoku Medical College, Department of Parasitology, through the kindness of Prof. S. Yokogawa, to whom our thanks are due. They are entirely different from the two species of *Stamnosoma metacercaria* found by us in dissections of *Ambassis buruensis*, mentioned in our previous report, and which, up to this time, we have consistently failed to recover experimentally. The *Echinochasmus* specimens recovered in our experiments are undoubtedly young forms of one single species; one of them shows one solitary egg; they are indistinguishable from *Echinochasmus novalichesensis*, a bird parasite reported from the Philippines by Tubangui in 1932.(16) The *Neodiplostomum* specimens obtained by us are immature forms of one single species, the identity of which we have not yet determined. In our previous feeding experiments with *Arius manillensis* and *Clarias batrachus* we also recovered a similar, immature *Neodiplostomum* species, but

TABLE 1.—*Feeding experiments with metacercaria from Ophicephalus striatus (dalag).*

Experimental animal.	Date of feeding.	Number of feedings.	Number of fish used.	Date of dissection.	Flukes identified.	Number of flukes recovered.
Dog	October 28, 1937, to January 5, 1938	43	91	January 7, 1938	*Haplorchis taichui*	949
					Haplorchis yokogamai	
					Neodiplostomum, immature	
Duck	October 27, 1937	1		October 28, 1937 [a]		0
Cat	January 21 to March 14, 1938	41	101	March 15, 1938	*Haplorchis taichui*	[b]
					Haplorchis tahokui	10
					Haplorchis calderoni	1
					Stamnosoma sp.	10
					Neodiplostomum, immature	
Control dog		0		December 10, 1937		0
Control duck		0		October 28, 1937		0
Control cat		0		February 1, 1938		0

[a] Died.

[b] Heavy infection.

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TABLE 2.—*Feeding experiments with metacercaria from Glossogobius giurus (bia).*

Experimental animal.	Date of feeding.	Number of feedings.	Number of fish used.	Date of dissection.	Flukes identified.	Number of flukes recovered.
Cat	October 29 to November 23, 1937	12	43	November 24, 1937	*Haplorchis calderoni*	14
					Stamnosoma sp.	13
					Haplorchis taikohui	1
Dog	December 4 to December 16,1937	8	30	December 17, 1937	*Haplorchis calderoni*	7
					Stamnosoma sp.	20
Do	February 11 to March 22, 1938	32	181	March 28, 1938	*Haplorchis calderoni*	(a)
					Stamnosoma sp.	(a)
					Echinochasmus sp.	1
Cat	June 15, 1938	1	(b)	June 17, 1938		0
Albino rat	do	1	(c)	June 19, 1938		0
Control cat		0		November 24, 1937		0
Control dog		0		December 6, 1937		0
Do		0		February 25, 1938		0
Control cat		0		June 10, 1938		0

[a] Many.

[b] One feeding of a single species of metacercaria which could not be recovered in previous experiments.

[c] One feeding of 99 metacercaria of the same species as in [b], which could not be recovered in previous experiments.

TABLE 3.—*Feeding experiments with metacercaria from Therapon plumbeus (ayuñgin).*

Experimental animal.	Date of feeding.	Number of feedings.	Number of fish used.	Date of dissection.	Flukes identified.	Number of flukes recovered.
Dog	October 25 to December 9, 1937	28	398	December 10, 1937	*Haplorchis sisoni*	(a)
					Stamnosoma sp.	4
Cat	January 21 to 31, 1938	8	95	February 1, 1938	*Haplorchis sisoni*	(b)
					Stamnosoma sp.	1
Dog	January 24 to February 3, 1938	9	140	February 4, 1938	*Neodiplostomum*, immature	(b)
					Haplorchis sisoni	64
					Stamnosoma sp.	1
					Neodiplostomum, immature	(b)
					Echinochasmus, immature	2
Do	February 5 to 26, 1938	17	218	February 27, 1938	*Haplorchis sisoni*	(b)
					Stamnosoma sp.	1
					Neodiplostomum, immature	(b)
					Echinochasmus sp.	1
Do	March 4 to August 5, 1938	82	926	August 9, 1938	*Haplorchis sisoni*	62
					Stictodora manilensis	5
					Haplorchis yokogawai	6
					Haplorchis taihokui	8
Cat	May 17 to August 16, 1938	47	598	August 17, 1938	*Haplorchis sisoni*	60
					Haplorchis taihokui	10
Control dog		0		December 10, 1937		0
Control cat		0		February 1, 1938		0
Control dog		0		February 3, 1938		0
Do		0		February 25, 1938		0
Do		0		February 27, 1938		0
2 control cats		0		June 10, 1938		0
Control cat		0		June 17, 1938		0

[a] Too many to count.

[b] Many.

TABLE 4.—*Feeding experiments with metacercaria from Gerris kapas (malacapas).*

Experimental animal.	Date of feeding.	Number of feedings.	Number of fish used.	Date of dissection.	Flukes identified.	Number of flukes recovered.
Dog	November 23, to December 6, 1937	5	48	December 8, 1937	*Haplorchis yokogawai*	121
					Heterophyes expectans	14
Control dog		0		December 6, 1937		0

TABLE 5.—*Feeding experiments with metacercaria from Gerris filamentosus (malacapas).*

Experimental animal.	Date of feeding.	Number of feedings.	Number of fish used.	Date of dissection.	Flukes identified.	Number of flukes recovered.
Dog	January 24 to February 5, 1938	12	77	February 7, 1938	*Haplorchis calderoni*	4
					Stictodora manilensis	4
					Heterophyes expectans	6
Do	February 10 to March 29, 1938	35	234	March 30, 1938	*Haplorchis calderoni*	[a]
					Haplorchis taihokui	2
					Stictodora manilensis	[b]
					Heterophyes expectans	3
Control dog		0		February 3, 1938		0
Do		0		February 25, 1938		0
Do		0		February 27, 1938		0

[a] Very many.

[b] Many.

TABLE 6.—*Feeding experiments with metacercaria from Creisson validus.*

Experimental animal.	Date of feeding.	Number of feedings.	Number of fish used.	Date of dissection.	Flukes identified.	Number of flukes recovered.
Dog	March 2 to May 7, 1938	32	163	May 11, 1938	*Haplorchis calderoni*	105
Control dog		0		February 25, 1938		0
Do		0		February 27, 1938		0

TABLE 7.—*Feeding experiments with metacercaria from Anabas testudineus (martinico).*

Experimental animal.	Date of feeding.	Number of feedings.	Number of fish used.	Date of dissection.	Flukes identified.	Number of flukes recovered.
Dog	February 11 to March 1, 1938	15	82	March 4, 1938	*Haplorchis calderoni* *Diorchitrema pseudocirrata* *Stamnosoma* sp.	(a)
Control dog		0		February 25, 1938		0
Do		0		February 27, 1938		0

[a] Light infection; most of the flukes were *H. calderoni*.

TABLE 8.—*Feeding experiments with metacercaria from Opiocara aporos.*

Experimental animal.	Date of feeding.	Number of feedings.	Number of fish used.	Date of dissection.	Flukes identified.	Number of flukes recovered.
Dog	February 11 to 14, 1938	3	5	February 25, 1938	*Echinochasmus* sp.	4
Control dog		0		do		0
Do		0		February 27, 1938		0

TABLE 9.—*Feeding experiments with metacercaria from Pelates quadrilineatus (babansi).*

Experimental animal.	Date of feeding.	Number of feedings.	Number of fish used.	Date of dissection.	Flukes identified.	Number of flukes recovered.
Dog	May 28 to August 3, 1938	34	408	August 4, 1938	*Stictodora manilensis*	43
					Heterophyes expectans	10
					Haplorchis calderoni	18
Control dog		0		February 25, 1938		0
Do		0		February 27, 1938		0

TABLE 10.—*Feeding experiments with metacercaria from Teuthis javus (samaral).*

Experimental animal.	Date of feeding.	Number of feedings.	Number of fish used.	Date of dissection.	Flukes identified.	Number of flukes recovered.
Cat	May 6 to August 1, 1938	23	126	August 5, 1938	*Heterophyes expectans*	20
					Haplorchis calderoni	46
					Haplorchis taihokui	1
Control cat		0		June 13, 1938		0

TABLE 11.—*Feeding experiments with metacercaria from Eleutheronema tetradactyla (mamale).*

Experimental animal.	Date of feeding.	Number of feedings.	Date of dissection.	Flukes identified.	Number of flukes recovered.
Cat	February 8 to July 4, 1938	3	August 16, 1938	*Haplorchis calderoni*	7
Control cat		0	Do.		0

TABLE 12.—*Feeding experiments with metacercaria from Arius manillensis (canduli).*

Experimental animal.	Date of feeding.	Number of feedings.	Date of dissection.	Flukes identified.	Number of flukes recovered.
Cat	November 22 to 26, 1937	2	December 4, 1937	*Haplorchis yokogawai*	78
				Neodiplostomum, immature	6
Control cat		0	November 27, 1937		0

TABLE 13.—*Feeding experiments with metacercaria from Ambassis buruensis.*

Experimental animal.	Date of feeding.	Number of feedings.	Number of fish used.	Date of dissection.	Flukes identified.	Number of flukes recovered.
Cat	May 16 to August 24, 1938	32	296	August 26, 1938	*Stictodora guerreroi*	19
					Heterophyes expectans	7
					Stictodora manilensis	8
					Haplorchis taihokui	3
					Haplorchis calderoni	7
Control cat		0		June 3, 1938		0

did not include it in the report because it is not a heterophyid. For the sake of completeness, however, we include it also in the present account. Two species of *Neodiplostomum* have been recorded in the Philippines; namely, *N. aluconis* Tubangui, 1933,(17) and *N. larai* Refuerzo et al., 1937.(15)

TABLE 14.—*Feeding experiments with metacercaria from Hemiramphus georgi.*

Experimental animal.	Date of feeding.	Number of feeding.	Number of fish used.
Cat	May 16 to September 2, 1938	34	181
Control cat		0	

Experimental animal.	Date of dissection.	Flukes identified.	Number of flukes recovered.
Cat	September 6, 1938	*Stictodora guerreroi*	43
		Haplorchis calderoni	25
		Heterophyes expectans	9
Control cat	June 3, 1938		0

In the experiment with *Hemiramphus georgi* (Table 14) previous findings are only partially duplicated, and no additional species are added. The experiment with *Ambassis buruensis* (Table 13) enriches our list for this fish with one more species of heterophyid, namely *Haplorchis pumilio* (= *Monorchotrema taihokui*), bringing up to 7 the total number of species of heterophyids so far recovered by us experimentally from this fish, and rounding up to 10 the species of heterophyid metacercaria which this fish harbors as second intermediate host. The experimental recovery of *Haplorchis pumilio* six times from 6 different species of fish (Tables 1, 2, 3, 5, 10, and 13) now for the first time definitely establishes its presence in this country. *Haplorchis taichui,* recovered in this series of experiments from one fish (Table 1) has already been reported from the Philippines by Africa et al.,(1) who found it in the small intestine of dogs and man. Two more piscine hosts (Tables 5 and 9) for *Stictodora manillensis,* 8 more (Tables 1, 2, 5, 6, 7, 9, 10, and 11) for *Haplorchis calderoni,* 2 more (Tables 1, 4) for *Haplorchis yokogawai,* 1 more (Table 7) for *Diorchitrema pseudocirrata,* and 4 more (Tables 4, 5, 9, and 10) for *Heterophyes expectans* have been determined by the persent series of feeding experiments. *Hemiramphus georgi* (Table 14) and *Ambassis buruensis* (Table 13) are hereby once more experimentally con-

TABLE 15.—*Names of flukes recovered experimentally from various species of fish.*

Fluke.	*Ophicephalus striatus.**	*Glossogobius giurus.**	*Therapon plumbeus.**	*Gerres kapas.**	*Gerres filamentosus.**	*Cretosoon rabidus.**	*Anabas testudineus.**	*Ophiocara aporos.**	*Pelates quadrilineatus.**	*Teuthis javus.**	*Elaeutheronema tetradactyla.**	*Hemiramphus georgii.*	*Ambassis buruensis.**	*Arius manillensis.*	*Clarias batrachus.*
1. *Stictodora guerreroi*													+		
2. *Stictodora manilensis*													+		
3. *Haplorchis calderoni*		+											+		
4. *Haplorchis stosoni*			+	+	+								+		
5. *Haplorchis yokogawai*													+		
6. *Haplorchis pumilio*													+		
7. *Haplorchis taichui*													+		
8. *Diorchitrema pseudocirrata*													+		
9. *Heterophyes expectans*													+		
10. *Stamnosoma formosanum*													+		
11. *Neodiplostomum* sp.?													+		
12. *Echinochasmus nonakichensis*													+		

firmed as piscine intermediate hosts of *Stictodora guerreroi*, *Haplorchis calderoni*, and *Heterophyes expectans*, and *Stictodora guerreroi*, *Stictodora manillensis*, *Haplorchis calderoni*, and *Heterophyes expectans*, respectively. And lastly, the present experiment with *Arius manillensis* once more shows that this fish is an intermediate host of *Haplorchis yokogawai* and a *Neodiplostomum* species.

SUMMARY

Table 15 summarizes the results obtained in the present series of feeding experiments. For completeness we have included in it all our previous findings with *Clarias batrachus*. The 6 trematode species marked "y," "e," and "n," respectively, are new additions to our list of experimental flukes. The asterisks indicate eleven new species of intermediate piscine hosts of Philippine heterophyids.

The existence of *Haplorchis pumilio* (= *Monorchotrema taihokui*) and *Stamnosoma formosanum* in the Philippines are herein reported for the first time. *Haplorchis sisoni*, a species new to science, discovered in this series of experimental feedings, has been reported in a separate paper by one of us (C.M.A.).

The richness and variety of Philippine fishes in trematode metacercaria, mostly heterophyid, are further made evident by the present experimental findings.

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ILLUSTRATIONS

[The grapic scale in each figure represents 1 inch.]

PLATE 1

FIG. 1. *Ambassis buruensis.*
2. *Hemiramphus georgi.*
3. *Hepsetia balabacensis.*
4. *Clarias batrachus.*
5. *Ophicephalus striatus.*

PLATE 2

F.G. 1. *Arius manillensis.*
2. *Ophiocara aporos.*
3. *Mugil dussumieri.*

PLATE 3

FIG. 1. *Glossogobius giurus.*
2. *Anabas testudineus.*
3. *Eleutheronema tetradactyla.*
4. *Gerris filamentosus.*

PLATE 4

FIG. 1. *Pelates quadrilineatus.*
2. *Teuthis javus.*
3. *Gerris kapas.*
4. *Therapon plumbeus.*
5. *Creisson validus.*

1

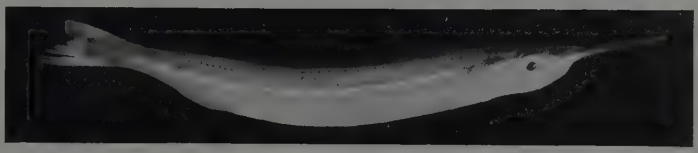

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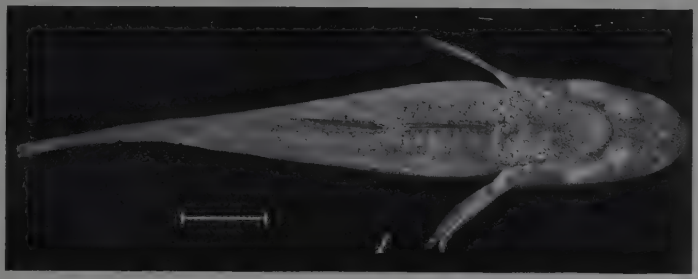
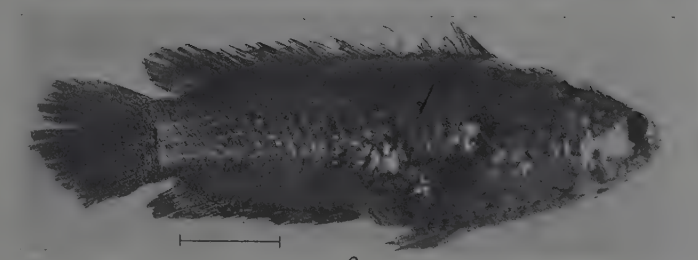
PLATE 1.

PLATE 2.





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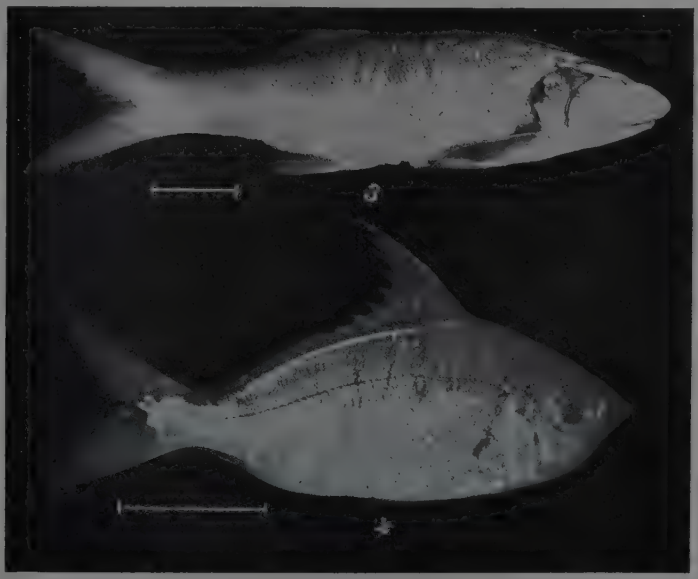

PLATE 3.

PLATE 4.

A RARE PARASITIC CRAB NEW TO PANGASINAN PROVINCE, LUZON

By GUILLERMO J. BLANCO and GUILLERMO L. ABLAN
Of the Division of Fisheries, Department of Agriculture and Commerce Manila

ONE PLATE

A. White (1846) described the genus *Xanthasia* to accommodate a female specimen of a single species of crab, *X. murigera*, of the family Pinnotheridæ. The origin of the material now deposited in the British Museum was vaguely given by White as "Philippine Islands." It was not until 1888 that de Man described the same species (two males and one female from *Tridacna*) from the material collected by Semper from Bohol and Burias Islands.

While working on the meat content of seventeen specimens of *Tridacna squamosa* Lamarck, collected from Lucap market, Alaminos, Pangasinan Province, September 23, 1938, the junior author obtained three gravid females and one male of *X. murigera* from the gills of these bivalves. Ninety-three years after the discovery of this species by White it is of geographical interest to note the new locality of this parasitic crab as being Luzon, Pangasinan Province, Alaminos.

Genus XANTHASIA White

XANTHASIA MURIGERA White. Plate 1, figs. 1 to 4.

WHITE, Ann. & Mag. Nat. Hist. 18 (1846) 176, pl. 2, fig. 3; DANA, U. S. Explor. Exped. Crust. 13 (1852) 384, pl. 24, fig. 6; DE MAN, Journ. Linn. Soc. London 22 (1888); BÜRGER, O. Zool. Jahrb. Syst. 8 (1895) 386, pl. 10, fig. 33; ESTAMPADOR, Philip. Journ. Sci. 62 (1937) 547.

Carapace with rough and irregular surface; margin, except frontal region, raised into an elevated ridge, curled around behind lateral knob on front of carapace. An elevated tubercle with lateral sharp edges and rough upper surface on middle of back of carapace. Two parallel longitudinal elevated keels between elevated tubercle and frontal region. Front of carapace projecting on each side, outside eyes; knobs present, making anterior part of carapace angular. Gravid female with extreme

bulging tail with prominent rounded keel down middle. Ambulatory legs short, cylindrical; claws thick, hooked, sharply pointed. Chela equal, small. Whitish in alcohol. The measurements and number of eggs of female specimens are given in Table 1.

TABLE 1.—*Measurements and number of eggs of female specimens.*

Specimen.	Carapace.		Number of eggs.
	Length.	Width.	
	mm.	*mm.*	
1	14	15	2,188
2	11	13	1,378
3	12	15	1,344

ILLUSTRATION

PLATE 1. XANTHASIA MURIGERA WHITE

[The graphic scale represents 1 inch.]

FIG. 1. Female, dorsal view.
2. Female, ventral view.
3. Male, dorsal view.
4. Male, ventral view.

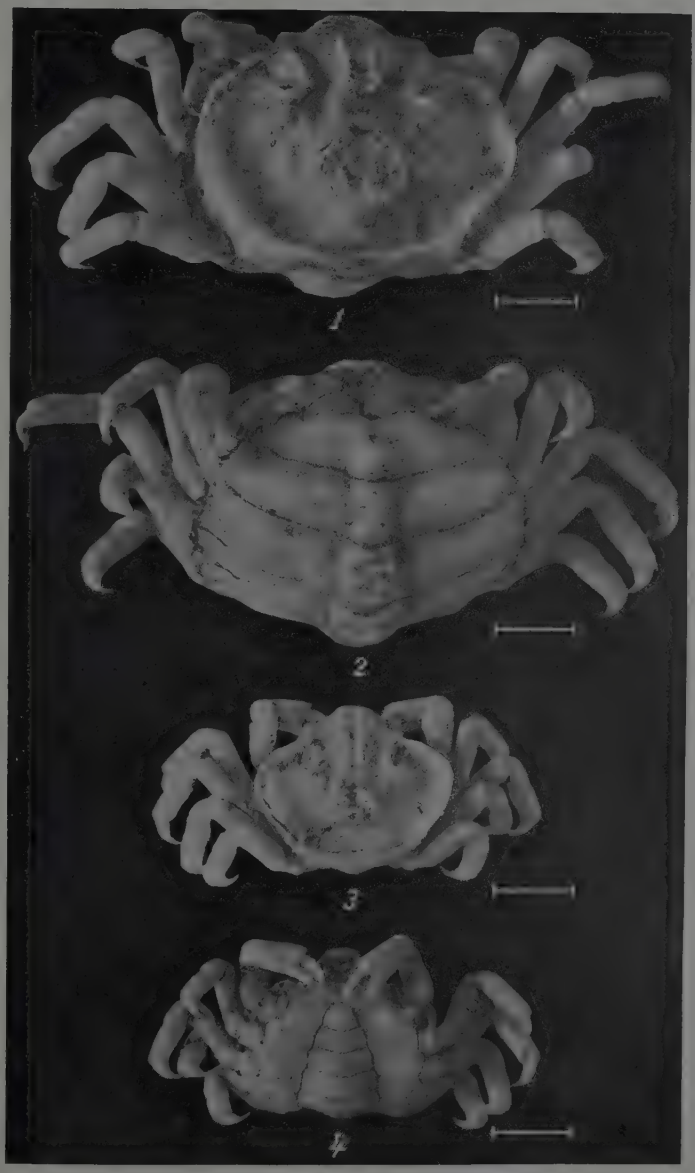

PLATE. 1. XANTHASIA MURIGERA WHITE.

VIABILITY OF THE COMMERCIAL OYSTER, OSTREA IREDALEI FAUSTINO

By Domiciano K. Villaluz

Of the Division of Fisheries, Department of Agriculture and Commerce Manila

THREE PLATES

Among the oysters raised in Bacoor Bay, Luzon, *Ostrea iredalei* Faustino is the most abundant. As early as 1935 oyster raisers using the hanging method of oyster culture began to recognize its superior quality. Requests for this species of oyster for propagation purposes have been numerous, and the Oyster Farm of the Division of Fisheries has tried to fill the demand to the best of its ability.

Oysters as food are beginning to be popular among Filipinos, because the public is being shown the sanitary conditions under which they are now being raised. In connection with the marketing of oysters, the important problem is to know how long they are capable of remaining alive outside of water, and to determine their viability, tests have been conducted in the Oyster Farm of the Division of Fisheries at Bacoor Bay.

DESCRIPTION

OSTREA IREDALEI Faustino. Plate 1, figs. 1 and 2.

Shell variable in shape, depending on mode of attachment; elongate, tongue-shaped, obliquely triangular or oblong. Outside of shell foliaceous, beak prominent. Left valve excavated, purple, right valve small, thin, flat, yellowish. Hinge toothless, inner margin of valve smooth. Interior of shell chalky white, muscle scar purple.

MATERIALS AND METHODS

Oysters raised in the Oyster Farm of the Division of Fisheries were utilized in these tests. Adult oysters about nine months old and of almost equal size were selected from among the bunches of oysters in the growing beds. Great care was taken not to destroy any part of the shell, especially the oyster "bill," so that

oyster liquor contained in the valves would not ooze out. Oysters used for observation were opened by means of a shucking knife which cuts and loosens the adductor muscles. The pericardial membrane was carefully opened to expose the heart and the heart beat observed. The sensitiveness of the tentacles of the mantle was tested by touching with the point of a dissecting needle. Throughout the experiment the following procedures were followed:

a. (1) Oysters contained in a sack and constantly moistened with sea water.
(2) Oysters contained in a sack and constantly moistened with fresh water.
b. (1) Oysters without mud contained in a wet sack.
(2) Oysters with mud contained in a wet sack.
c. (1) Oysters without mud contained in a dry sack.
(2) Oysters with mud contained in a dry sack.
d. (1) Oysters contained in a sack moistened from time to time and exposed to sunshine.
(2) Oysters contained in a dry sack and exposed to sunshine.
e. (1) Oysters with mud, exposed under shade.
(2) Oysters without mud, exposed under shade.

Three sets of tests were performed, the first June 27, the second July 5, and the third July 14, 1938.

OBSERVATIONS AND RESULTS OF TESTS

a. (*1*) *Oysters contained in a sack constantly moistened with sea water.*—The oysters treated were examined on the second and third days. It was observed that all of them were closed during these two days. On the second day seven oysters were carefully opened by cutting the strong adductor muscles. It was found that the valves were full of oyster liquor, the tentacles of the mantle were very sensitive, and the heart appeared to be beating normally. On the third day five oysters were opened. The adductor muscles were declining in strength and the valves were easily separated. The oyster liquor was comparatively lessened in amount, the tentacles of the mantle were not sensitive, and the heart beats were hardly perceptible.

(*2*) *Oysters contained in a sack and constantly moistened with fresh water.*—The oysters were still closed on the third day. Four oysters were carefully opened, and the valves were

observed to be very tight and the adductor muscles strong. The heart beats could hardly be discerned; tentacles of the mantle were sensitive and the valves filled with oyster liquor.

b. (*1*) *Oysters without mud contained in a wet sack.*—The oysters were examined on the second day and all were found closed. Five oysters were opened and carefully observed. It was found that the adductor muscles were strong; the valves filled with liquor; the heart beat rather slowly, and the tentacles were still sensitive. On the fourth day almost all of the oysters were found gaping. Oyster fluid was absent in all of them, the heart was no longer beating, and the tentacles of the mantle were not sensitive.

(*2*) *Oysters with mud contained in a wet sack.*—On the second day five oysters were opened. The adductor muscles were strong, the valves tightly closed, and oyster liquor was present inside. The heart beat normally and the tentacles of the mantle were sensitive. On the fourth day most of the oysters were gaping, and those closed were forced open. Their valves were easily separated and the adductor muscles very much weakened. The oyster liquor was almost consumed and the heart was no longer beating. The tentacles of the mantle were not sensitive.

c. (*1*) *Oysters without mud contained in a dry sack.*—On the fourth day the valves of oysters under this condition were found gaping. The oyster liquor was almost consumed in all of them, the heart was no longer beating, the tentacles of the mantle were not sensitive, and the valves were easily separated due to the weakening of the adductor muscles.

(*2*) *Oysters with mud contained in a dry sack.*—On the fourth day almost all of the oysters opened. Oyster liquor was absent in the gaping oysters while in those that were forced open this fluid was present only in small amounts. In both cases the heart had stopped beating and the tentacles of the mantle were no longer sensitive.

d. (*1*) *Oysters contained in a sack moistened from time to time and exposed to sunshine.*—The second day the oyster valves were found closed. Five oysters were carefully opened and observed. The valves were filled with oyster liquor, the heart was still beating, and the tentacles of the mantle were very sensitive. On the third day some of the oysters were gaping, and contained a very small amount of oyster liquor, and the heart was no longer beating. Some of the closed oysters were carefully opened and their valves found still filled

with fluid. The heart had stopped beating and the tentacles were no longer sensitive.

(*2*) *Oysters contained in a dry sack and exposed to sunshine.*—When the oysters were examined the second day, a small amount of oyster liquor was found in the valves, and the heart was beating very slowly. The tentacles of the mantle were sensitive. On the third day most of the oysters were gaping. Oyster liquor was absent in the valves and the heart had stopped beating. When the closed oysters were forced open the tentacles were no longer sensitive and the heart had stopped beating. Small amounts of oyster liquor were still present inside the valves.

e. (*1*) *Oysters with mud, exposed under shade.*—The second day five oysters were opened. The valves were full of oyster liquor, the heart beats appeared normal, and the tentacles of the mantle were sensitive. On the fourth day most of the oysters were gaping, were without oyster liquor, the heart was no longer beating, and the tentacles were not senstive. The closed oysters on opening were found to contain small amounts of oyster liquor, the heart was no longer beating, and the tentacles were not sensitive.

(*2*) *Oysters without mud, exposed under shade.*—The second day the oysters that were opened were full of oyster liquor, the heart was still beating, and the tentacles were very sensitive. On the fourth day most of the oysters were gaping while some remained closed. Both gaping and closed oysters were dead.

The results of the tests on viability are shown in Table 1.

DISCUSSION OF RESULTS

Oysters contained in a sack constantly moistened with sea water and those contained in a sack constantly moistened with fresh water were able to live an average of ninety hours. Oysters outside of water always keep their valves tightly closed so that the amount of either salt or fresh water that could enter them must have been very insignificant.

Oysters without mud and kept in a wet sack were able to live as long as those with mud kept in a wet sack. Both groups of oysters lived an average of ninety hours. Mud adhering to the surface of oyster shells seemed to have no great effect on viability.

Oysters under sunshine and moistened from time to time lived an average of sixty-four hours, while those under sunshine kept in a dry sack lived an average of sixty-three hours.

TABLE 1.—*Results of tests on viability of Ostrea iredalei.*

Procedure.	Dead. Date.	Time.	Number of hours alive.
	FIRST TRIAL		
	[Set 6:00 p. m., June 27, 1938.]		
	1938	*A. M.*	
Oyster wet with sea water	July 1	12:00	90
Oysters wet with fresh water	do	12:00	90
Oysters without mud in wet sack	do	12:00	90
Oysters with mud in wet sack	do	12:00	90
Oysters without mud in dry sack	do	11:30	89.5
Oysters with mud in dry sack	do	11:30	89.5
Oysters under sunshine in wet sack	June 30	8:00	62
Oysters under sunshine in dry sack	do	6:30	61
Oysters with mud exposed under shade	July 1	7:30	85.5
Oysters without mud exposed under shade	do	7:00	85
	SECOND TRIAL		
	[Set 2:00 p. m., July 5, 1938.]		
Oysters wet with sea water	July 9	12:00	94
Oysters wet with fresh water	do	12:00	94
Oysters without mud in wet sack	do	12:00	94
Oysters with mud in wet sack	do	12:00	94
Oysters without mud in dry sack	do	11:00	93
Oysters with mud in dry sack	do	11:00	93
Oysters under sunshine in wet sack	July 8	8:00	66
Oysters under sunshine in dry sack	do	6:30	64.5
Oysters with mud exposed under shade	July 9	8:00	89
Oysters without mud exposed under shade	do	7:30	88.5
	THIRD TRIAL		
	[Set 5:00 p. m., July 14, 1938.]		
Oysters wet with sea water	July 18	10:00	89
Oysters wet with fresh water	do	10:00	89
Oysters without mud in wet sack	do	10:00	89
Oysters with mud in wet sack	do	10:00	89
Oysters without mud in dry sack	do	9:30	88.5
Oysters with mud in dry sack	do	9:30	88.5
Oysters under sunshine in wet sack	July 17	10:00	65
Oysters under sunshine in dry sack	do	8:00	63
Oysters with mud exposed under shade	July 18	8:30	87.5
Oysters without mud exposed under shade	do	8:00	87

CONCLUSIONS AND RECOMMENDATIONS

1. *Ostrea iredalei* can live outside of water for an average of ninety hours.

2. The cooling effect of mud and water on the oyster is very insignificant in terms of viability.

3. High temperature shortens the life of oysters.

4. Shortening of the period of life of the oyster due to exposure under shade is insignificant.

5. Oysters in a sack can live under sunshine for two days.

6. It is safe to eat oysters forty-eight hours outside of water.

7. Oysters should always be kept out of direct sunshine.

8. The meat of oysters with open valves should never be eaten, as these oysters are usually dead and in the process of decomposition.

ILLUSTRATIONS

PLATE 1. OSTREA IREDALEI FAUSTINO

FIG. 1. With open valves.
2. About eight months old.

PLATE 2

Bunches of *Ostrea iredalei* Faustino, from the Oyster Farm of the Division of Fisheries.

PLATE 3

Heaps of shells of *Ostrea iredalei* Faustino, used as cultch in the Oyster Farm of the Division of Fisheries.

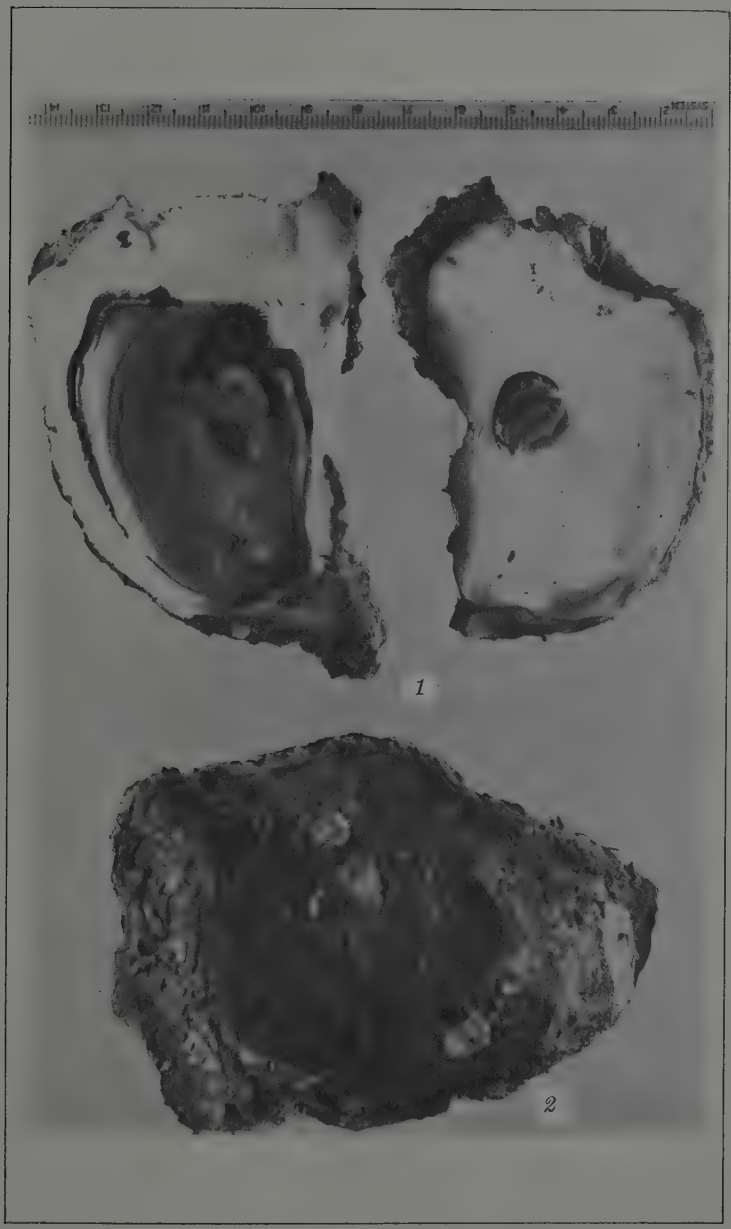

PLATE 1. OSTREA IREDALEI FAUSTINO.

PLATE 2. OSTREA IREDALEI FAUSTINO.

PLATE 3. OSTREA IREDALEI FAUSTINO.

BOOKS

Books reviewed here have been selected from books received by the Philippine Journal of Science from time to time and acknowledged in this section.

REVIEWS

Practical Seismology and Seismic Prospecting. By L. D. Leet. New York, D. Appleton-Century company, incorporated, c1938. 430 pp., illus. Price $6.

This is the most interesting and comprehensive treatise on seismology that has appeared in English up to the present time. Chapter and section titles will indicate how thoroughly the field has been covered: Cause of Earthquakes; Distribution of Earthquakes; Elasticity and Elastic Waves; Instruments; Instrumental Observations; Effects of Earthquakes; Important Earthquakes of History; History of Seismology; Seismic Prospecting.

The chapters on Instruments and Instrumental Observations are very complete and practical. Considerable attention is given to the Benioff instruments, the latest and most promising in the field of seismology. The chapter on the Propagation of Elastic Waves emphasizes waves in the outer layers of the earth's crust because of their importance in seismic prospecting. The selection of important earthquakes is well made and each is written up in a most informative way. The selection is governed by actual seismic importance, and not entirely by loss of life or material damage. The classification of some large earthquakes by the Richter magnitude scale is interesting. Holden's dynamical equivalents of the Rossi-Forel scale are quoted but they are considerably higher than Cancani's values which are favored by engineers.

The history of seismology is given in nine pages, which contain an extraordinary amount of biographical and scientific data pertaining to the development of the science. The book terminates with two chapters on seismic prospecting which reduce to practice the principles given in the earlier chapters on elastic waves. A list of important patents is given on seismic prospecting and some court actions involved in connection with them.

There is a wealth of maps, diagrams and cuts which contribute greatly to an understanding of the matter. References are cited as footnotes.—W. C. R.

Manual of Roentgenological Technique. By L. R. Sante. Ann Arbor, Michigan, Edwards Brothers, Inc., 1938. 228 pp., front., illus. Price $4.50.

Although this book of Professor Sante represents a compilation of the work of others, as he has mentioned in his preface, it may be considered a great contribution to the list of books dealing with X-Ray technique. The simplicity of his language and the systematic procedure followed make the book understandable and useful to the vast army of students of radiology.

The roentgenological consideration, giving the hows and whys for every standard position selected in the radiography of the different parts of the body, is the most outstanding feature of the book, distinguishing it from other treatises on the same subject.

The volume is worth having because it will be of service not only to X-Ray technicians and radiologists but also to every physician who in his practice has to make X-Rays required in the analysis of his cases.

The book is profusely illustrated.—P. S. C.

The Soybean Industry. By A. A. Horvath. New York, The Chemical publishing Co. of New York, Inc., 1938. 221 pp. Price, $4.

The phenomenal development of soybean as an article of world commerce gave rise to a dearth of soybean literature. The present book seems to be the first attempt at assembling together in a brief and easily readable form scattered technical information about the soybean industry. Doctor Horvath, himself an eminent chemist and an authority on soybean manufactures, made a review of the more important literature on the chemistry of soybean and its products, and presents it as a popular and easily read publication.

The book is divided into 20 short chapters with a list of useful references. In the first chapters are discussed the methods of processing soybean into different products and the properties and industrial uses of such products. A brief account of the development of the soybean-oil industry is given, followed by a discussion of pressure oil milling versus solvent extraction. The various methods of oil extraction are discussed rather in detail. Also, the advantages and disadvantages of each are pointed out.

In the latter chapters an extended account of soybean oil, its properties, methods of refining, and industrial uses is presented. Similarly treated are the uses of soybean proteins. The methods of extracting soybean phosphatides and proteins are given in detail. The manufacture of plactics, adhesives, sizing materials, and others is well covered in the closing chapters. This book should be a good reference for all those interested in the soybean industry.—P. A. R.

Transactions of the American Institute of Mining and Metallurgical Engineers (Incorporated) Volume 127. Petroleum Development and Technology 1938. Petroleum Division. Papers and Discussions Presented Before the Division at Meetings Held at Los Angeles, October 1, 1937; Oklahoma City, October 7 to 9, 1937; New York, February 14 to 18, 1938. New York, American Institute of mining and metallurgical engineers, Inc., c1938. 744 pp., illus. Price, $5.

This volume maintains the usual high standard of publications of the A. I. M. E. in presenting a series of technical papers covering the progress of current research and development of Petroleum Engineering, including the papers presented at the sectional meetings of the Petroleum Division of the Institute, held during the year 1937–1938 at Los Angeles, Oklahoma City, and New York. Fundamental problems of oil production treated in separate papers by engineers from various fields in the United States include the "Spacing of oil wells" to obtain maximum recovery consistent with economic considerations, "Excessive pressures and pressure variations with depth of petroleum reservoirs in the Gulf Coast Region," "Pressure drilling operations at Kettleman Hills, and effect on initial production rates," and "Desalting of crude oils." The three most recently discovered notable oilfields in California are described by engineers operating in the respective fields. A chapter on engineering research includes papers on the various live and pertinent problems of oil technology introduced by one discussing the perennial question of the "Origin of petroleum."

The importance and interest of many of the papers are augmented by the inclusion, thereafter, of a stenographic report of the discussion of the particular issues involved in the respective papers.

Nearly one-half of the volume is devoted to oil production during the year 1937, in various oil-producing states of the Union, countries and oilfields. Thirty-one papers are included, giving a résumé of oil production by States and fields in the

United States and twenty-four reporting production and oil development in foreign countries.

A very brief chapter on "Refinery engineering for 1937" concludes the volume. Some papers include lists of references. There are many graphs and tables.—H. N. J.

Research and Statistical Methodology. Books and Reviews 1933–1938. By Oscar Krisen Buros, Editor. New Brunswick, Rutgers University Press, 1938. 100 pp. Price, $1.25.

Books and monographs on statistics and statistical research methodology, reviews of which are published elsewhere, are not always available to teachers or researchers. Buros, with the aid of Rutgers University, has accomplished an admirable piece of work to meet such a need, by gathering into one book of a hundred pages, scattered literature that makes publications on statistical subjects easily accessible.

The book under review contains (*a*) a classified index to books on research methodology and statistical methods; (*b*) "collated excerpts" of critical reviews of these books or monographs published recently; and (*c*) a comprehensive index to titles and authors separately of matters treated in the book. As the title of the book indicates, only books and monographs written and published recently, between January 1, 1933, and November 15, 1938, are included by the editor. Besides the most critical portions of the reviews of these books being excerpted and collated and published herein, full bibliographic information as to American and English prices and publishers is also given.

Reviews of statistical and research methodology books in all fields, such as actuarial mathematics, agriculture, biology, business, economics, education, engineering, forestry, history, marketing, medicine, psychology, sociology, vital statistics, and the like, from all available sources, published in Belgium, Canada, China, England, Holland, India, Scotland, South Africa, Sweden, the United States, and other countries, have been excerpted and collated in this book, a fact which therefore makes this volume a very handy guide in locating and selecting the particular type of book which the reader in statistics needs.

Although the present book is capable of enlargement by including standard books in statistics published earlier than 1933 and written in languages other than English, Buros and Rutgers University have given us a very valuable reference book on statistics and research methodology, the selection of such pub-

lished books being confined to a period in which new developments in the theory of statistics have taken place.—T. J. J.

Rubber-Growing: Elementary Principles and Practice. Compiled and prepared for publication by A. Moore. Kuala Lumpur, The Rubber Research Institute of Malaya, printed by Kyle, Palmer & Co., Ltd., 1938. 82 pp., illus. Price, 50 cents.

This article contains valuable information of the cultivation of rubber trees, the extraction and preparation of latex, and the protection of the trees from their various plant and animal enemies which rubber planters ought to be familiar with. It answers fully the long-felt need for a concrete guide in the selection of land suitable for rubber growing. It also treats of the right distance in planting as well as the correct way and the time of tapping the trees, the right procedure of making high quality sheet rubber, and the proper care and marketing of the product with a view to obtaining the maximum production at the minimum expense. This article is instructive as it presents fundamental principles underlying rubber culture in simple language free from the many technical terms which are often confusing to the layman.

While this publication is intended primarily for the enlightenment of rubber planters, particularly the small estate holders in Malaya, it is also of interest to persons interested in the proper care of plants and the conservation of the soil, like the agriculturist, the horticulturist, the landscape gardener, and the forester of other tropical countries. This manual contains photographs and diagrams.—M. G.

Tropical Nursing. A Handbook for Nurses and Others Going Abroad. By A. L. Gregg. With a Foreword by the Hon. Sir Arthur Stanley. London, Cassell and Co., Ltd. 199 pp., illus. Price, 6s.

This is a handbook that answers many of the questions and problems which almost daily confront the nurses working in tropical countries, more particularly those actively engaged in field work in remote and isolated places where the services of medical men are not generally available. It is precisely under such circumstances that the book fulfills a most necessary service, for in it the nurse as well as the layman finds a ready reference for information, advice, and direction to follow in coping with the different ailments and emergencies met with in the East.

As the title suggests, liberal space is devoted to the description of tropical diseases, giving their causes, the symptoms of

the different stages of their development, their treatment, and their prophylaxis. Malaria, dysentery, beriberi, and the different worm diseases which are most prevalent are discussed more in detail than the rest.

The book is interesting, instructive, and comprehensive. It is a wealth of knowledge to which field nurses, especially, should have access at all times for reference. Its size permits it to be carried conveniently in a pocket or in a bag.—E. M. A.

Some Methods for the Detection and Estimation of Poisonous Gases and Vapors in the Air. A Practical Manual for the Industrial Hygienist. By A. S. Zhitkova. Edited and with an introduction by Prof. S. I. Kaplun. Translated under direction of Joseph B. Ficklen. West Hartford, Connecticut, Service to Industry, c1936. 198 pp., illus. Price, $3.

This book is a valuable guide in the estimation of noxious materials found in industrial air. In 33 chapters it discusses the properties and estimation of substances usually dispersed in air in modern industrial plants. Some of the methods and apparatus described are new and ingeniously devised to solve some of the problems in this new field of applied chemistry. Micro-analysis, "specific" reaction (detection without isolation), and colorimetric and nephelometric procedures are frequently employed when the nature of the air dispersion does not permit the use of ordinary methods. Concise and helpful information on the occurrence and toxicity of each material treated is given at the beginning of each chapter. The manner of computation is clearly discussed, making it easy for even beginners to understand. This book is illustrated and includes a bibliography. It is primarily useful to industrial hygienists and chemists.

—R. T. S.

New and Nonofficial Remedies, 1938, Containing Descriptions of the Articles which Stand Accepted by the Council on Pharmacy and Chemistry of the American Medical Association, January 1, 1938. Chicago, American Medical Association, c1938. 590 pp. biblio., index, supplement.

The 1938 edition of this book fills a need always felt by the different professionals in the medical sciences. With the United States Pharmacopœia, the National Formulary in the United States, and the Extra Pharmacopœia in England as its predecessors, this book was published for the first time by the Council of Pharmacy and Chemistry established in 1905 by the American Medical Association. If this book, was, in its earlier

editions, a casual reference, it now has become useful and a necessity.

In the publication of this book rules were observed carefully so as to maintain perfect coördination with those for the United States Pharmacopœia and National Formulary started by the American Pharmaceutical Association years previous to 1888, when its first edition appeared. The enormous materials are well disposed in the book. Though they are discussed by groups, the various remedies are described in alphabetical order so that any substance is easily found.

The scope of this book is extensive, in the sense that it gives information on each remedy and a view of the different substances in actual use, including vaccines, sera, vitamins, hormones, and the like. Some of them may appear as a duplication of the United States Pharmacopœia or National Formulary. What characterizes this book is the complete and exhaustive list of all the pharmaceuticals and their manufactures. The acceptance of these preparations does not imply recommendation and the physicians should be aware of this distinction.

At the end of the book there are a general index, an index to distributors, and a bibliographical index of proprietary and unofficial articles not included in the text, although some of them are in vogue to some extent. To mention a few, we have optochin, the well-discussed sulphanilamide, and antuitrin.

The New Non-official Remedies should be on the desk of every physician. It should accompany the United States Pharmacopœia and National Formulary in the laboratory of every drug store. Chemists will find it an interesting reference.—M. V. R.

Practical Tree Surgery. By Millard F. Blair. Boston, The Christopher Publishing House, c1937. 297 pp., front., illus. Price, $4.

This book, the latest on tree surgery, embodies the most advanced and modern methods of practical tree surgery. The technical and practical knowledge with which the author is equipped makes him an authority on this subject and the most qualified to write on it. He discusses topics that are not only relevant but also essential to the broad aspects of the subject.

The inclusiveness and thoroughness of the book will strike the reader at once. The topics are grouped into thirty-two chapters, arranged in the most systematic manner. The author deals briefly with general characters and types of deciduous and coniferous trees, palms, and ornamental plants. The prin-

cipal insect and fungous enemies of these groups of plants, the injuries that these enemies produce, and the control measures for all of them, are discussed. A brief discussion is also devoted to beneficial fungi, the mycorrhiza. For the main subject the author discusses at some length tree structures and their function, principle of growth; trimming, planting, and pruning; types of braces and methods of bracing trees; cavities and their repairs, cavity bracing, filling, disinfecting, and water proofing; grafting and budding; propagation, natural and artificial; and pollination in relation to the development of new varieties.

It is noteworthy that throughout the discussion the author painstakingly avoids the use of highly technical terms without sacrificing thought or thoughts he wants to convey to the reader, so that any one with a limited knowledge of the fundamentals of biology can grasp without much difficulty the principles involved in the practice of tree surgery.

Although the book is designed for use in the American temperate zone, the principles laid down in it can be used as guides to tree surgery in other temperate and tropical countries of the world. In view of this the book is highly commended as an important reference, particularly for forest pathologists and horticulturists. The book contains illustrations and a short list of references.—E. F. R.

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